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KEITHLEY

Model 2000 Multimeter

User's Manual

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Model 2000 Multimeter
User's Manual

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KEITHLEY Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a ⏚ screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The ⚠ symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The ⚠ symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Table of Contents

1 General Information

Introduction....1-2
Feature overview....1-2
Warranty information....1-3
Manual addenda....1-3
Safety symbols and terms....1-3
Specifications....1-3
Inspections....1-4
Options and accessories....1-5

2 Basic Measurements

Introduction....2-2
Front panel summary....2-3
Rear panel summary....2-6
Power-up....2-8
Display....2-17
Measuring voltage....2-18
Measuring current....2-22
Measuring resistance....2-24
Measuring frequency and period....2-26
Measuring temperature....2-28
Math....2-30
Measuring continuity....2-34
Testing diodes....2-35

3 Measurement Options

Introduction....3-2
Measurement configuration....3-3
Trigger operations....3-8
Buffer operations....3-17
Limit operations....3-20
Scan operations....3-22
System operations....3-32

4 Remote Operation

Introduction....4-2
Selecting a language....4-4
RS-232 operation....4-6
GPIB bus operation and reference....4-9
Status structure....4-19

Trigger model (GPIB operation) 4-29
Programming syntax 4-32
Common commands 4-39

5 SCPI Command Reference

SCPI Signal oriented measurement commands 5-3
SCPI command subsystems reference tables 5-7
Calculate subsystem 5-20
DISPlay subsystem 5-26
:FORMat subsystem 5-28
ROUTe subsystem 5-32
[SENSe[1]] subsystem 5-37
STATus subsystem 5-52
:SYSTem subsystem 5-61
:TRACe subsystem 5-68
Trigger subsystem 5-70
:UNIT subsystem 5-74

A Specifications

Accuracy calculations A-7
Optimizing measurement accuracy A-10
Optimizing measurement speed A-11

B Status and Error Messages

C Example Programs

Program examples C-2

D Models 196/199 and 8840A/8842A Commands

E IEEE-488 Bus Overview

Introduction E-2
Bus description E-4
Bus lines E-6
Bus commands E-8
Interface function codes E-15

F IEEE-488 and SCPI Conformance Information

Introduction F-2

List of Illustrations

2 Basic Measurements

Model 2000 front panel 2-3
Model 2000 rear panel 2-6
Power module 2-8
DC and AC voltage measurements 2-19
DC and AC current measurements....2-22
Two- and four-wire resistance measurements....2-25
Frequency and period measurements....2-27
Thermocouple temperature measurements 2-28
Continuity measurements 2-34
Diode testing....2-35

3 Measurement Options

Moving average and repeating filters....3-4
Front panel triggering without stepping/scanning 3-8
Rear panel pinout....3-11
Trigger link input pulse specifications (EXT TRIG) 3-12
Trigger link output pulse specifications (VMC)....3-12
DUT test system 3-13
Trigger link connections 3-13
Operation model for triggering example 3-14
DIN to BNC trigger cable....3-16
Buffer locations....3-18
Using limit test to sort 100Ω, 10% resistors....3-21
Front panel triggering with stepping....3-24
Front panel triggering with scanning....3-25
Internal scanning example with reading count option....3-27
Internal scanning example with timer and delay options 3-29
External scanning example with Model 7001 3-31

4 Remote Operation

RS-232 interface connector 4-8
IEEE-488 connector....4-10
IEEE-488 connections 4-10
IEEE-488 connector location....4-11
Model 2000 status register structure....4-19
Standard event status 4-22
Operation event status....4-22
Measurement event status....4-23
Questionable event status....4-23
Status byte and Service Request (SRQ)....4-25
Trigger model (GPIB operation)....4-29

Device action (trigger model) 4-31
Standard event enable register 4-41
Standard event status register 4-43
Service request enable register 4-49
Status byte register 4-51

5 SCPI Command Reference

ASCII data format 5-28
IEEE754 single precision data format (32 data bits) 5-29
IEEE754 double precision data format (64 data bits) 5-29
Measurement event register 5-53
Questionable event register 5-54
Operation event register 5-55
Measurement event enable register 5-57
Questionable event enable register 5-57
Operation event enable register 5-57
Key-press codes 5-66

E IEEE-488 Bus Overview

IEEE-488 bus configuration E-5
IEEE-488 handshake sequence E-7
Command codes E-12

List of Tables

2 Basic Measurements

Fuse ratings 2-9
Factory defaults 2-13
Crest factor limitations 2-18

3 Measurement Options

Rate settings for the measurement functions 3-7
Auto delay settings 3-9
Bus commands parameters for stepping and scanning counters 3-28

4 Remote Operation

Language supported 4-4
RS-232 connector pinout 4-8
General bus commands and associated statements 4-14
IEEE-488.2 common commands and queries 4-39

5 SCPI Command Reference

Signal oriented measurement command summary 5-3
CALCulate command summary 5-8
DISPlay command summary 5-9
FORMat command summary 5-9
ROUTe command summary 5-10
SENSe command summary 5-10
STATus command summary 5-16
SYSTem command summary 5-17
TRACe command summary 5-17
Trigger command summary 5-18
UNIT command summary 5-19

B Status and Error Messages

Status and error messages B-2

D Models 196/199 and 8840A/8842A Commands

Models 196/199 device-dependent command summary D-2
Models 8840A/8842A device-dependent command Summary D-6

E IEEE-488 Bus Overview

IEEE-488 bus command summary E-8
Hexadecimal and decimal command codes E-11
Typical addressed command sequence E-13
Typical addressed command sequence E-13
IEEE command groups E-14
Model 2000 interface function codes E-15

F IEEE-488 and SCPI Conformance Information

IEEE-488 documentation requirements F-2
Coupled commands F-4

1
General Information

Introduction

This section contains general information about the Model 2000 Multimeter. The information is organized as follows:

- Feature overview
- Warranty information
- Manual addenda
- Safety symbols and terms
- Specifications
- Inspection
- Options and accessories

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S. and Canada only). Worldwide phone numbers are listed at the front of this manual.

Feature overview

The Model 2000 is a 6½-digit high-performance digital multimeter. It has 0.002% 90-day basic DC voltage accuracy and 0.008% 90-day basic resistance accuracy. At 6½ digits, the multimeter delivers 50 triggered readings/sec over the IEEE-488 bus. At 4½ digits, it can read up to 2000 readings/sec into its internal buffer. The Model 2000 has broad measurement ranges:

- DC voltage from 0.1µV to 1000V.
- AC (RMS) voltage from 0.1µV to 750V, 1000V peak.
- DC current from 10nA to 3A.
- AC (RMS) current from 1µA to 3A.
- Two and four-wire resistance from 100µΩ to 120MΩ.
- Frequency from 3Hz to 500kHz.
- Thermocouple temperature from -200°C to +1372°C.

Some additional capabilities of the Model 2000 include:

- Full range of functions — In addition to those listed above, the Model 2000 functions include period, dB, dBm, continuity, diode testing, mX+b, and percent.
- Optional scanning — For internal scanning, options include the Model 2000-SCAN, a 10-channel, general-purpose card, and the Model 2001-TCSCAN, a 9-channel, thermocouple card with a built-in cold junction. For external scanning, the Model 2000 is compatible with Keithley's Model 7001 and 7002 switch matrices and cards.
- Programming languages and remote interfaces — The Model 2000 offers three programming language choices (SCPI, Keithley Models 196/199, and Fluke 8840A/8842A) and two remote interface ports (IEEE-488/GPIB and RS-232C).
- Reading and setup storage — Up to 1024 readings and two setups (user and factory defaults) can be stored and recalled.
- Closed-cover calibration — The instrument can be calibrated either from the front panel or remote interface.

Warranty information

Warranty information is located at the front of this instruction manual. Should your Model 2000 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

Manual addenda

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual.

Safety symbols and terms

The following symbols and terms may be found on the instrument or used in this manual.

The symbol on the instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on the instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Specifications

Full Model 2000 specifications are included in Appendix A.

Inspection

The Model 2000 was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (Note: There may be a protective film over the display lens, which can be removed.) Report any damage to the shipping agent immediately. Save the original packing carton for possible future reshipment. The following items are included with every Model 2000 order:

- Model 2000 Multimeter with line cord.
- Safety test leads (Model 1751).
- Accessories as ordered.
- Certificate of calibration.
- Model 2000 User's Manual (P/N 2000-900-00).
- Model 2000 Calibration Manual (P/N 2000-905-00).
- Model 2000 Support Software Disk including TestPoint run-time applications, TestPoint instrument libraries for GPIB and RS-232, and QuickBASIC examples.

If an additional manual is required, order the appropriate manual package. The manual packages include a manual and any pertinent addenda.

Options and accessories

The following options and accessories are available from Keithley for use with the Model 2000.

Scanner cards

Model 2000-SCAN: This is a 10-channel scanner card that installs in the option slot of the Model 2000. Channels can be configured for 2-pole or 4-pole operation. Included are two pairs of leads for connection to Model 2000 rear panel inputs (Keithley P/N CA-109).

Model 2001-TCSCAN: This is a thermocouple scanner card that installs in the option slot of the Model 2000. The card has nine analog input channels that can be used for high-accuracy, high-speed scanning. A built-in temperature reference allows multi-channel, cold-junction compensated temperature measurements using thermocouples.

General purpose probes

Model 1754 Universal Test Lead Kit: Consists of one set of test leads (0.9m), two spade lugs, two banana plugs, two hooks, and two alligator clips.

Model 8605 High Performance Modular Test Leads: Consists of two high voltage (1000V) test probes and leads. The test leads are terminated with a banana plug with retractable sheath on each end.

Model 8606 High Performance Probe Tip Kit: Consists of two spade lugs, two alligator clips, and two spring hook test probes. (The spade lugs and alligator clips are rated at 30V RMS, 42.4V peak; the test probes are rated at 1000V.) These components are for use with high performance test leads terminated with banana plugs, such as the Model 8605.

The following test leads and probes are rated at 30V RMS, 42.4V peak:

Models 5805 and 5805-12 Kelvin Probes: Consists of two spring-loaded Kelvin test probes with banana plug termination. Designed for instruments that measure 4-terminal resistance. The Model 5805 is 0.9m long; the Model 5805-12 is 3.6m long.

Model 5806 Kelvin Clip Lead Set: Includes two Kelvin clip test leads (0.9m) with banana plug termination. Designed for instruments that measure 4-terminal resistance. A set of eight replacement rubber bands is available as Keithley P/N GA-22.

Model 8604 SMD Probe Set: Consists of two test leads (0.9m), each terminated with a surface mount device "grabber" clip on one end and a banana plug with a retractable sheath on the other end.

Low thermal probes

Model 8610 Low Thermal Shorting Plug: Consists of four banana plugs mounted to a 1-inch square circuit board, interconnected to provide a short circuit among all plugs.

Model 8611 Low Thermal Patch Leads: Consists of two test leads (0.9m), each with a banana plug with a retractable sheath at each end. These leads minimize the thermally-induced offsets that can be created by test leads.

Model 8612 Low Thermal Spade Leads: Consists of two test leads (0.9m), each terminated with a spade lug on one end and a banana plug with a retractable sheath on the other end. These leads minimize the thermally-induced offsets that can be created by test leads.

Cables and adapters

Models 7007-1 and 7007-2 Shielded GPIB Cables: Connect the Model 2000 to the GPIB bus using shielded cables and connectors to reduce electromagnetic interference (EMI). The Model 7007-1 is 1m long; the Model 7007-2 is 2m long.

Models 8501-1 and 8501-2 Trigger Link Cables: Connect the Model 2000 to other instruments with Trigger Link connectors (e.g., Model 7001 Switch System). The Model 8501-1 is 1m long; the Model 8501-2 is 2m long.

Model 8502 Trigger Link Adapter: Allows you to connect any of the six Trigger Link lines of the Model 2000 to instruments that use the standard BNC trigger connectors.

Model 8504 DIN to BNC Trigger Cable: Allows you to connect Trigger Link lines one (Voltmeter Complete) and two (External Trigger) of the Model 2000 to instruments that use BNC trigger connectors. The Model 8504 is 1m long.

Rack mount kits

Model 4288-1 Single Fixed Rack Mount Kit: Mounts a single Model 2000 in a standard 19-inch rack.

Model 4288-2 Side-by-Side Rack Mount Kit: Mounts two instruments (Models 182, 428, 486, 487, 2000, 2001, 2002, 6517, 7001) side-by-side in a standard 19-inch rack.

Model 4288-3 Side-by-Side Rack Mount Kit: Mounts a Model 2000 and a Model 199 side-by-side in a standard 19-inch rack.

Model 4288-4 Side-by-Side Rack Mount Kit: Mounts a Model 2000 and a 5.25-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775, etc.) side-by-side in a standard 19-inch rack.

Carrying case

Model 1050 Padded Carrying Case: A carrying case for a Model 2000. Includes handles and shoulder strap.

2
Basic Measurements

Introduction

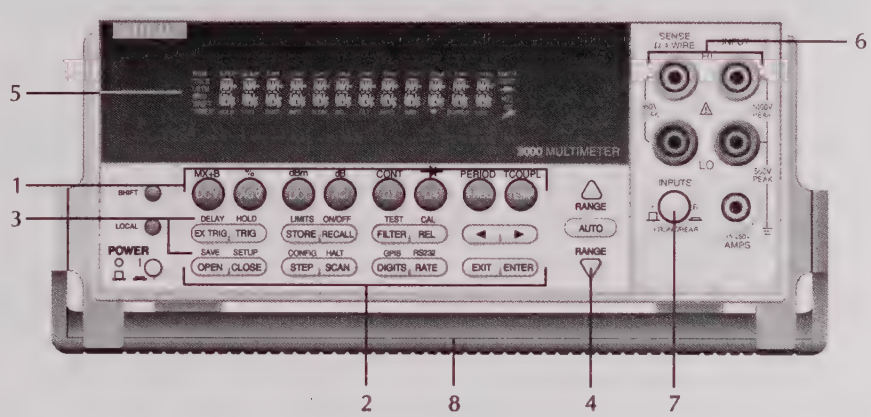
This section summarizes front panel operation of the Model 2000. It is organized as follows:

- **Front panel summary** — Includes an illustration and summarizes keys, display, and connections.
- **Rear panel summary** — Includes an illustration and summarizes connections.
- **Power-up** — Describes connecting the instrument to line power, the power-up sequence, the warm-up time, and default conditions.
- **Display** — Discusses the display format and messages that may appear while using the instrument.
- **Measuring voltage** — Covers DC and AC voltage measurement connections and low level voltage considerations.
- **Measuring current** — Covers DC and AC current measurement connections and current fuse replacement.
- **Measuring resistance** — Details two and four-wire measurement connections and shielding considerations.
- **Measuring frequency and period** — Covers frequency and period measurement connections.
- **Measuring temperature** — Describes the use of thermocouples for temperature measurements.
- **Math** — Covers the mX+b, percent, dBm, and dB math functions performed on single readings.
- **Measuring continuity** — Explains setting up and measuring continuity of a circuit.
- **Testing diodes** — Describes testing general-purpose and zener diodes.

Front panel summary

The front panel of the Model 2000 is shown in Figure 2-1. This figure includes important abbreviated information that should be reviewed before operating the instrument.

Figure 2-1
Model 2000 front panel



1 Function keys (shifted and unshifted)

Select measurement function (DC and AC voltage, DC and AC current, 2-wire and 4-wire resistance, frequency, period, temperature with thermocouples), math function (mX+b, %, dBm, dB), or special function (continuity, diode test).

2 Operation keys

EXTRIG	Selects external triggers (front panel, bus, trigger link) as the trigger source.
TRIG	Triggers a measurement from the front panel.
STORE	Enables reading storage.
RECALL	Displays stored readings and buffer statistics (maximum, minimum, average, standard deviation). Use ▲ and ▼ to scroll through buffer; use ◄ and ► to toggle between reading number and reading.
FILTER	Displays digital filter status for present function and toggles filter on/off.
REL	Enables/disables relative reading on present function.
◄ and ►	Moves through selections within functions and operations. If scanner card installed, manually scans channels.
OPEN	Opens all channels on internal scanner card; stops scanning.
CLOSE	Closes selected internal channel.
STEP	Steps through channels; sends a trigger after each channel.
SCAN	Scans through channels; sends a trigger after last channel.
DIGITS	Changes number of digits of resolution.
RATE	Changes reading rate: fast, medium, slow.
EXIT	Cancels selection, moves back to measurement display.
ENTER	Accepts selection, moves to next choice or back to measurement display.
SHIFT	Used to access shifted keys.
LOCAL	Cancels GPIB remote mode.

3 Shifted operation keys

DELAY	Sets user delay between trigger and measurement.
HOLD	Holds reading when the selected number of samples is within the selected tolerance.
LIMITS	Sets upper and lower limit values for readings.
ON/OFF	Enables/disables limits; selects beeper operation for limit testing.
TEST	Selects built-in tests, diagnostics, display test.
CAL	Accesses calibration.
SAVE	Saves present configuration for power-on user default.
SETUP	Restores factory or user default configuration.
CONFIG	Selects minimum/maximum channels, timer, and reading count for step/scan.
HALT	Turns off step/scan.
GPIB	Enables/disables GPIB interface; selects address and language.
RS232	Enables/disables RS-232 interface; selects baud rate, flow control, terminator.

4 Range keys

▲	Moves to higher range; increments digit; moves to next selection.
▼	Moves to lower range; decrements digit; moves to previous selection.
AUTO	Enables/disables autorange.

5 Annunciators

*(asterisk)	Reading being stored.
→|← (diode)	Instrument is in diode testing function.
))) (speaker)	Beeper on for continuity or limits testing.
▲▼ (more)	Indicates additional selections are available.
4W	4-wire resistance reading displayed.
AUTO	Autoranging enabled.
BUFFER	Recalling stored readings.
CH 1-10	Displayed internal channel is closed.
ERR	Questionable reading; invalid cal step.
FAST	Fast reading rate.
FILT	Digital filter enabled.
HOLD	Instrument is in hold mode.
LSTN	Instrument addressed to listen over GPIB.
MATH	Math function (mX+b, %, dB, dBm) enabled.
MED	Medium reading rate.
REAR	Reading acquired from rear inputs.
REL	Relative reading displayed.
REM	Instrument is in GPIB remote mode.
SCAN	Instrument is in scan mode.
SHIFT	Accessing shifted keys.
SLOW	Slow reading rate.
SRQ	Service request over GPIB.
STAT	Displaying buffer statistics.
STEP	Instrument is in step mode.
TALK	Instrument addressed to talk over GPIB.
TIMER	Timed scans in use.
TRIG	Indicates external trigger (front panel, bus, trigger link) selected.

6 Input connections

INPUT HI and LO	Used for making DC volts, AC volts, 2-wire resistance measurements.
AMPS	Used in conjunction with INPUT LO to make DC current and AC current measurements. Also holds current input fuse (3A, 250V, fast blow, 5×20mm).
SENSE Ω4 WIRE HI and LO	Used with INPUT HI and LO to make 4-wire resistance measurements.

7 INPUTS

Selects input connections on front or rear panel.

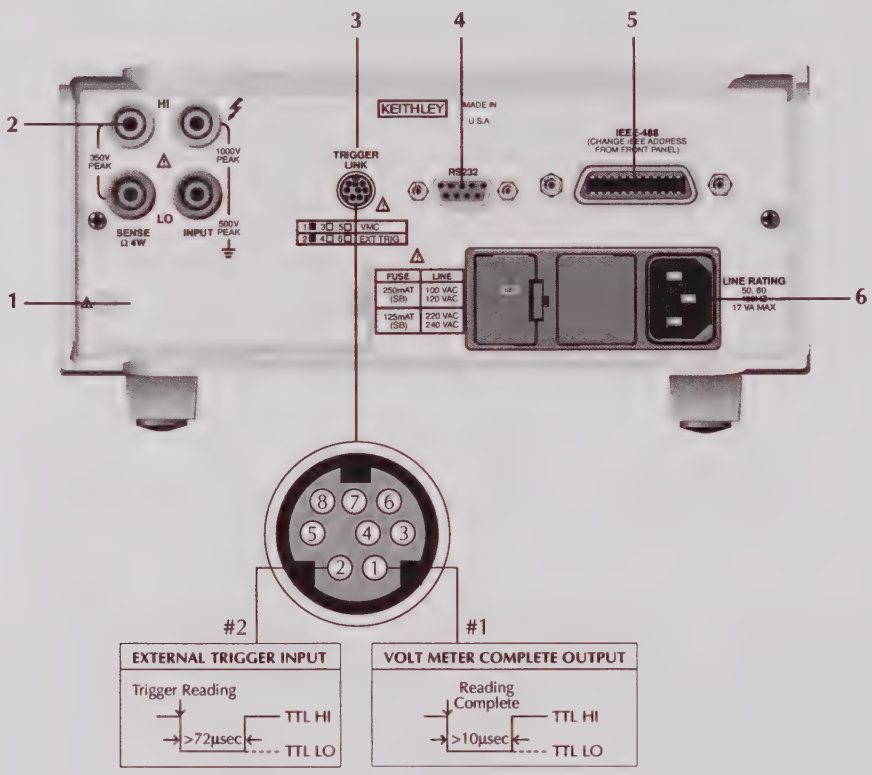
8 Handle

Pull out and rotate to desired position.

Rear panel summary

The rear panel of the Model 2000 is shown in Figure 2-2. This figure includes important abbreviated information that should be reviewed before operating the instrument.

Figure 2-2
Model 2000 rear panel



1 Option slot

An optional scanner card (Model 2000-SCAN, 2001-SCAN, or 2001-TCSCAN) installs in this slot.

2 Input connections

INPUT HI and LO	Used for making DC volts, AC volts, 2-wire resistance measurements and for connecting scanner card.
SENSE Ω4 WIRE HI and LO	Used with INPUT HI and LO to make 4-wire resistance measurements and also for connecting scanner card.

3 TRIGGER LINK

One 8-pin micro-DIN connector for sending and receiving trigger pulses among other instruments. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502, 8504.

4 RS-232

Connector for RS-232 operation. Use a straight-through (not null modem) DB-9 cable.

5 IEEE-488

Connector for IEEE-488 (GPIB) operation. Use a shielded cable, such as Models 7007-1 and 7007-2.

6 Power module

Contains the AC line receptacle, power line fuse, and line voltage setting. The Model 2000 can be configured for line voltages of 100V/120V/220V/240VAC at line frequencies of 45Hz to 66Hz or 360Hz to 440Hz.

Power-up

Line power connection

Follow the procedure below to connect the Model 2000 to line power and turn on the instrument.

1. Check to see that the line voltage selected on the rear panel (see Figure 2-3) is correct for the operating voltage in your area. If not, refer to the next procedure, "Setting line voltage and replacing fuse."

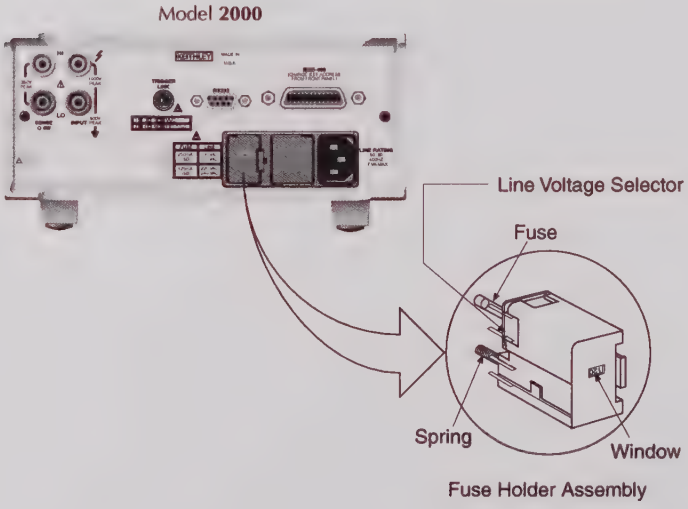
CAUTION ***Operating the instrument on an incorrect line voltage may cause damage to the instrument, possibly voiding the warranty.***

2. Before plugging in the power cord, make sure that the front panel power switch is in the off (0) position.
3. Connect the female end of the supplied power cord to the AC receptacle on the rear panel. Connect the other end of the power cord to a grounded AC outlet.

WARNING ***The power cord supplied with the Model 2000 contains a separate ground wire for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.***

4. Turn on the instrument by pressing the front panel power switch to the on (1) position.

Figure 2-3
Power module



Setting line voltage and replacing fuse

A rear panel fuse located next to the AC receptacle protects the power line input of the instrument. If the line voltage setting needs to be changed or the line fuse needs to be replaced, perform the following steps.

WARNING ***Make sure the instrument is disconnected from the AC line and other equipment before changing the line voltage setting or replacing the line fuse.***

1. Place the tip of a flat-blade screwdriver into the power module by the fuse holder assembly (see Figure 2-3). Gently push in and to the left. Release pressure on the assembly and its internal spring will push it out of the power module.
2. Remove the fuse and replace it with the type listed in Table 2-1.

CAUTION ***For continued protection against fire or instrument damage, only replace fuse with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse. See the optional Model 2000 Repair Manual for troubleshooting information.***

3. If configuring the instrument for a different line voltage, remove the line voltage selector from the assembly and rotate it to the proper position. When the selector is installed into the fuse holder assembly, the correct line voltage appears inverted in the window.
4. Install the fuse holder assembly into the power module by pushing it in until it locks in place.

Table 2-1
Fuse ratings

Line voltage	Fuse rating	Keithley P/N
100/120V	0.25A slow-blow 5×20mm	FU-96-4
220/240V	0.125A slow-blow 5×20mm	FU-91

Power-up sequence

On power-up, the Model 2000 performs self-tests on its EPROM and RAM and momentarily lights all segments and annunciators. If a failure is detected, the instrument momentarily displays an error message and the ERR annunciator turns on. (Error messages are listed in Appendix B.)

NOTE *If a problem develops while the instrument is under warranty, return it to Keithley Instruments, Inc., for repair.*

If the instrument passes the self-tests, the firmware revision levels are displayed. An example of this display is:

REV: A01 A02

where: A01 is the main board ROM revision.
A02 is the display board ROM revision.

After the power-up sequence, the instrument begins its normal display of readings.

High energy circuit safety precautions

To optimize safety when measuring voltage in high energy distribution circuits, read and use the directions in the following warning.

WARNING ***Dangerous arcs of an explosive nature in a high energy circuit can cause severe personal injury or death. If the multimeter is connected to a high energy circuit when set to a current range, low resistance range, or any other low impedance range, the circuit is virtually shorted. Dangerous arcing can result even when the multimeter is set to a voltage range if the minimum voltage spacing is reduced in the external connections.***

When making measurements in high energy circuits, use test leads that meet the following requirements:

- Test leads should be fully insulated.
- Only use test leads that can be connected to the circuit (e.g., alligator clips, spade lugs, etc.) for hands-off measurements.
- Do not use test leads that decrease voltage spacing. These diminishes arc protection and create a hazardous condition.

Use the following sequence when testing power circuits:

1. De-energize the circuit using the regular installed connect-disconnect device, such as a circuit breaker, main switch, etc.
2. Attach the test leads to the circuit under test. Use appropriate safety rated test leads for this application.
3. Set the multimeter to the proper function and range.
4. Energize the circuit using the installed connect-disconnect device and make measurements without disconnecting the multimeter.
5. De-energize the circuit using the installed connect-disconnect device.
6. Disconnect the test leads from the circuit under test.

WARNING ***The maximum common-mode voltage (voltage between INPUT LO and the chassis ground) is 500V peak. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.***

Power-on defaults

Power-on defaults are the settings the instrument assumes when it is turned on. The Model 2000 offers two choices for the settings: factory and user. The power-on default will be the last configuration you saved. The SAVE and SETUP keys select the two choices of power-on defaults.

To save present configuration as user settings:

1. Configure the instrument as desired for USER default.
2. Press SHIFT then SAVE.
3. Use the ▲ and ▼ keys to select YES or NO.
4. Press ENTER.

To restore factory or user settings:

1. Press SHIFT then SETUP.
2. Use the ▲ and ▼ keys to select FACTory or USER.
3. Press ENTER.

Since the basic measurement procedures in this manual assume the factory defaults, reset the instrument to the factory settings when following step-by-step procedures. Table 2-2 lists the factory default settings.

Table 2-2
Factory defaults

Setting	Factory default
Autozero	On
Buffer	No effect
Continuity	
Beeper	On
Digits	4½
Rate	Fast (0.1 PLC)
Threshold	10Ω
Current (AC and DC)	
Digits (AC)	5½
Digits (DC)	6½
Filter	On
Count	10
Mode	Moving average
Range	Auto
Relative	Off
Value	0.0
Rate (AC)	Medium*
Rate (DC)	Medium (1 PLC)
Diode test	
Digits	6½
Range	1mA
Rate	Medium (1 PLC)
Frequency and Period	
Digits	6½
Range	10V
Relative	Off
Value	0.0
Rate	Slow (1 sec)
Function	DCV
GPIB	No effect
Address	(16 at factory)
Language	(SCPI at factory)
Limits	Off
Beeper	Never
High limit	+1
Low limit	-1
mX+b	Off
Scale factor	1.0
Offset	0.0
Percent	Off
References	1.0

Table 2-2 (cont.)
Factory defaults

Setting	Factory default
Resistance (2-wire and 4-wire)	
Digits	6½
Filter	On
Count	10
Mode	Moving average
Range	Auto
Relative	Off
Value	0.0
Rate	Medium (1 PLC)
RS-232	Off
Baud	No effect
Flow	No effect
Tx term	No effect
Scanning	Off
Channels	1-10
Mode	Internal
Temperature	
Digits	5½
Filter	On
Count	10
Mode	Moving average
Junction	Simulated
Temperature	23°C
Relative	Off
Value	0.0
Rate	Medium (1 PLC)
Thermocouple	J
Units	°C
Triggers	
Continuous	On
Delay	Auto
Source	Immediate

Table 2-2 (cont.)
Factory defaults

Setting	Factory default
Voltage (AC and DC)	
dB reference	No effect
dBm reference	75Ω
Digits (AC)	5½
Digits (DC)	6½
Filter	On
Count	10
Mode	Moving average
Range	Auto
Relative	Off
Value	0.0
Rate (AC)	Medium*
Rate (DC)	Medium (1 PLC)

*DETector:BANDwidth 30

GPIB primary address

The GPIB primary address of the instrument must be the same as the primary address you specify in the controller's programming language. The default primary address of the instrument is 16, but you can set the address to any value from 0 to 30 by using the following step by step instructions.

1. Press SHIFT then GPIB.
2. Use the ▲ and ▼ keys to select ADDRess. Or, press ENTER. Once you have pressed ENTER, the unit automatically displays the address selection.
3. Use the ◄ and ► keys to toggle from ADDRess to the numeric entry. Notice the values are blinking.
4. Use the ▲ and ▼ keys to change the numeric entries to the desired address.
5. Press ENTER.

See Section Four — Remote Operation for more GPIB information.

Warm-up time

The Model 2000 is ready for use as soon as the power-up sequence has completed. However, to achieve rated accuracy, allow the instrument to warm up for one hour. If the instrument has been subjected to extreme temperatures, allow additional time for internal temperatures to stabilize.

Display

The display of the Model 2000 is primarily used to display readings, along with the units and type of measurement. Annunciators are located on the top, bottom, right, and left of the reading or message display. The annunciators indicate various states of operation. See Figure 2-1 for a complete listing of annunciators.

Status and error messages

Status and error messages are displayed momentarily. During Model 2000 operation and programming, you will encounter a number of front panel messages. Typical messages are either of status or error variety, as listed in Appendix B.

Measuring voltage

The Model 2000 can make DCV measurements from 0.1µV to 1000V and ACV measurements from 0.1µV to 750V RMS, 1000V peak.

Connections

Assuming factory default conditions, the basic procedure is as follows:

1. Connect test leads to the INPUT HI and LO terminals. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the measurement function by pressing DCV or ACV.
3. Pressing AUTO toggles autoranging. Notice the AUTO annunciator is displayed with autoranging. If you want manual ranging, use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected voltage.
4. Connect test leads to the source as shown in Figure 2-4.

CAUTION ***Do not apply more than 1000V peak to the input or instrument damage may occur. The voltage limit is subject to the 8×10^7 V•Hz product.***

5. Observe the display. If the "OVERFLOW" message is displayed, select a higher range until an o normal reading is displayed (or press AUTO for autoranging). Use the lowest possible range for the best resolution.
6. Take readings from the display.

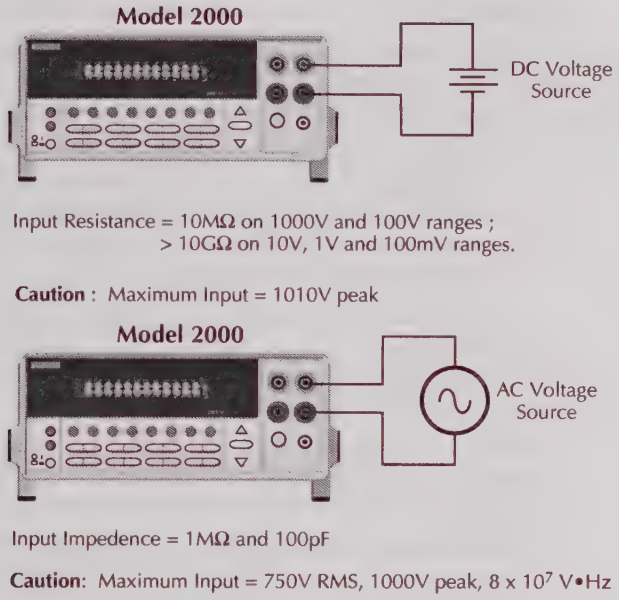
Crest factor

AC voltage and current accuracies are affected by the crest factor of the waveform, the ratio of the peak value to the RMS value. Table 2-3 lists the fundamental frequencies at which the corresponding crest factor must be taken into account for accuracy calculations.

Table 2-3
Crest factor limitations

Crest factor	Fundamental frequency
2	50kHz
3	3kHz
4-5	1kHz

Figure 2-4
DC and AC voltage measurements


Model 2000
DC Voltage Source
Input Resistance = 10MΩ on 1000V and 100V ranges ;
> 10GΩ on 10V, 1V and 100mV ranges.
Caution : Maximum Input = 1010V peak
Model 2000
AC Voltage Source
Input Impedence = 1MΩ and 100pF
Caution: Maximum Input = 750V RMS, 1000V peak, 8 x 10^7 V•Hz

Low level considerations

For sensitive measurements, external considerations beyond the Model 2000 affect the accuracy. Effects not noticeable when working with higher voltages are significant in microvolt signals. The Model 2000 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors that affect accuracy, including stray signal pick-up and thermal offsets.

Shielding

AC voltages that are extremely large compared with the DC signal to be measured may produce an erroneous output. Therefore, to minimize AC interference, the circuit should be shielded with the shield connected to the Model 2000 INPUT LO (particularly for low level sources). Improper shielding can cause the Model 2000 to behave in one or more of the following ways:

- Unexpected offset voltages.
- Inconsistent readings between ranges.
- Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 2000 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

NOTE *Shielded cables should be used for input circuits to avoid interference caused by conducting RF.*

Thermal EMFs

Thermal EMFs (thermoelectric potentials) are generated by thermal differences between the junctions of dissimilar metals. These can be large compared to the signal that the Model 2000 can measure. Thermal EMFs can cause the following conditions:

- Instability or zero offset is much higher than expected.
- The reading is sensitive to (and responds to) temperature changes. This effect can be demonstrated by touching the circuit, by placing a heat source near the circuit, or by a regular pattern of instability (corresponding to changes in sunlight or the activation of heating and air conditioning systems).

To minimize the drift caused by thermal EMFs, use copper leads to connect the circuit to the Model 2000. A banana plug generates a few microvolts. A clean copper conductor such as #10 bus wire is ideal for this application. The leads to the input may be shielded or unshielded, as necessary. Refer to "Shielding".

Widely varying temperatures within the circuit can also create thermal EMFs. Therefore, maintain constant temperatures to minimize these thermal EMFs. A shielded enclosure around the circuit under test also helps by minimizing air currents.

The REL control can be used to null out constant offset voltages.

NOTE *Additional thermals may be generated by the optional scanner cards.*

AC voltage offset

The Model 2000, at 5½ digits resolution, will typically display 100 counts of offset on AC volts with the input shorted. This offset is caused by the offset of the TRMS converter. This offset will not affect reading accuracy and should not be zeroed out using the REL feature. The following equation expresses how this offset (V_{OFFSET}) is added to the signal input (V_{IN}):

$$\text{Displayed reading} = \sqrt{(V_{IN})^2 + (V_{OFFSET})^2}$$

Example: Range = 1VAC
Offset = 100 counts (1.0mV)
Input = 100mV RMS

$$\text{Displayed reading} = \sqrt{(100\text{mV})^2 + (1.0\text{mV})^2}$$

$$= \sqrt{(0.01\text{V}) + (1 \times 10^{-6}\text{V})}$$

$$\text{Displayed reading} = 0.100005$$

The offset is seen as the last digit, which is not displayed. Therefore, the offset is negligible. If the REL feature were used to zero the display, the 100 counts of offset would be subtracted from V_{IN}, resulting in an error of 100 counts in the displayed reading.

See Section 3 — Measurement Options for information that explain the configuration options for DC and AC voltage measurements.

Measuring current

The Model 2000 can make DCI measurements from 10nA to 3A and ACI measurements from 1µAm to 3A RMS.

NOTE *See the previous discussion about crest factor in "Measuring voltage" in this section.*

Connections

Assuming factory default conditions, the basic procedure is as follows:

1. Connect test leads to the AMPS and INPUT LO terminals. The front inputs must be used; place the INPUTS button in the FRONT position.
2. Select the measurement function by pressing DCI or ACI.
3. Pressing AUTO toggles autoranging. Notice the AUTO annunciator is displayed with autoranging. If you want manual ranging, use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected current.
4. Connect test leads to the source as shown in Figure 2-5.

CAUTION ***Do not apply more than 3A, 250V to the input or the AMPS fuse will open-circuit.***

5. Observe the display. If the "OVERFLOW" message is displayed, select a higher range until a normal reading is displayed (or press AUTO for autoranging). Use the lowest possible range for the best resolution.
6. Take readings from the display.

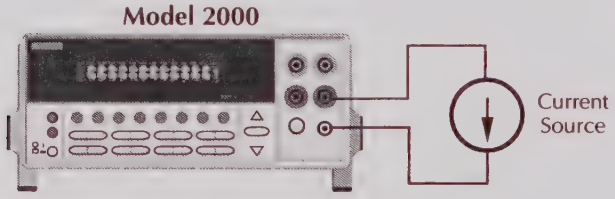


Figure 2-5
DC and AC current measurements

AMPS fuse replacement

WARNING ***Make sure the instrument is disconnected from the power line and other equipment before replacing the AMPS fuse.***

1. Turn off the power and disconnect the power line and test leads.
2. From the front panel, gently push in the AMPS jack with your thumb and rotate the fuse carrier one-quarter turn counter-clockwise. Release pressure on the jack and its internal spring will push the jack out of the socket.
3. Remove the fuse and replace it with the same type (3A, 250V, fast blow, 5 × 20mm). The Keithley part number is FU-99-1.

CAUTION ***Do not use a fuse with a higher current rating than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse. See the optional Model 2000 Repair Manual for troubleshooting information.***

4. Install the new fuse by reversing the procedure above.

See Section 3 — Measurement Options for information that explains the configuration options for DC and AC current measurements.

Measuring resistance

The Model 2000 can make 2-wire and 4-wire resistance measurements from 100μΩ to 120MΩ.

Connections

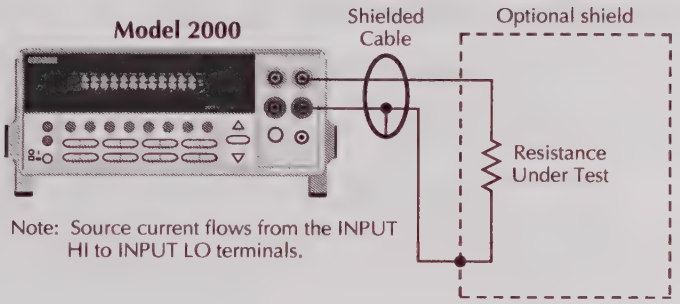
Assuming factory default conditions, the basic procedure is as follows:

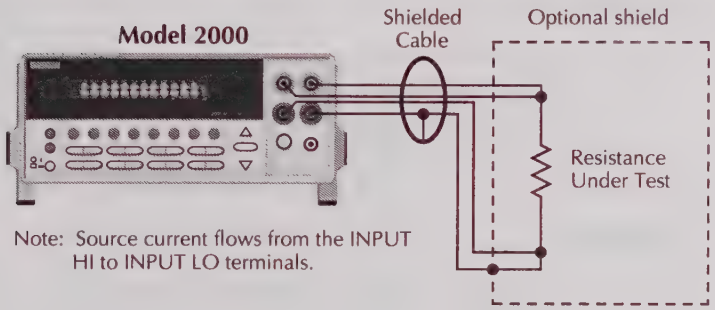
1. Connect test leads to the Model 2000 as follows:
   A. For Ω2-wire, connect the test leads to INPUT HI and LO.
   B. For Ω4-wire, connect the test leads to INPUT HI and LO, and SENSE Ω4 WIRE HI and LO. Recommended Kelvin test probes include the Keithley Models 5805 and 5806. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the measurement function by pressing Ω2 or Ω4.
3. Pressing AUTO toggles autoranging. Notice the AUTO annunciator is displayed with autoranging. If you want manual ranging, use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected resistance.
4. Connect test leads to the resistance as shown in Figure 2-6.

CAUTION ***Do not apply more than 1000V peak between INPUT HI and LO or instrument damage may occur.***

5. Observe the display. If the "OVERFLOW" message is displayed, select a higher range until a normal reading is displayed. Use the lowest possible range for the best resolution.
6. Take a reading from the display.

Figure 2-6
Two- and four-wire resistance measurements


Model 2000
Shielded Cable
Optional shield
Resistance Under Test
Note: Source current flows from the INPUT HI to INPUT LO terminals.


Model 2000
Shielded Cable
Optional shield
Resistance Under Test
Note: Source current flows from the INPUT HI to INPUT LO terminals.

Shielding

To achieve a stable reading, it helps to shield resistances greater than 100kΩ. Place the resistance in a shielded enclosure and connect the shield to the INPUT LO terminal of the instrument electrically.

See Section 3—Measurement Options for information that explains the configuration options for 2-wire and 4-wire resistance measurements.

Measuring frequency and period

The Model 2000 can make frequency measurements from 3Hz to 500kHz on voltage ranges of 100mV, 1V, 10V, 100V, and 750V. Period measurements can be taken from 2µs to 333ms on the same voltage ranges as the frequency.

The instrument uses the volts input terminals to measure frequency. The AC voltage range can be changed with the RANGE ▲ and ▼ keys. The signal voltage must be greater than 10% of the full-scale range.

CAUTION ***The voltage limit is subject to the 8×10^7 V•Hz product.***

Trigger level

Frequency and Period use a zero-crossing trigger, meaning that a count is taken when the frequency crosses the zero level. The Model 2000 uses a reciprocal counting technique to measure frequency and period. This method generates constant measurement resolution for any input frequency. The multimeter's AC voltage measurement section performs input signal conditioning.

Gate time

The gate time is the amount of time the Model 2000 uses to sample frequency or period readings. All settings of the RATE key (FAST, MEDium, SLOW) yield a gate time of one second.

The Model 2000 completes a reading when it receives its first zero-crossing after the gate time expires. In other words, the reading is completed 1/2 cycle after the gate time has expired. For example, with a 1sec gate time to sample a 3Hz frequency, you may wait up to 3 seconds before the Model 2000 returns a reading.

Connections

Assuming factory default conditions, the basic procedure is as follows:

1. Connect test leads to the INPUT HI and LO terminals of the Model 2000. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the FREQ or PERIOD function.
3. Connect test leads to the source as shown in Figure 2-7.

CAUTION ***Do not exceed 1000V peak between INPUT HI and INPUT LO or instrument damage may occur.***

4. Take a reading from the display.

See Section 3—Measurement Options for information that explains the configuration options for frequency and period measurements.

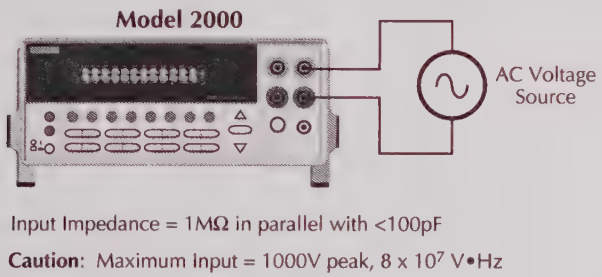


Figure 2-7
Frequency and period measurements

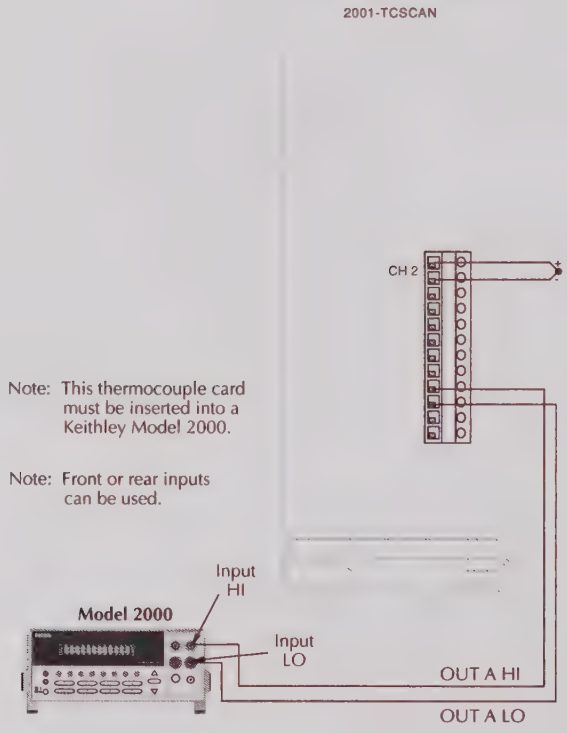
Measuring temperature

The Model 2000 measures temperature with thermocouples. The temperature measurement ranges available depend on the type of thermocouple chosen.

Thermocouples can be connected to the Model 2001-TCSCAN card, which plugs into the option slot of the Model 2000, or to an external thermocouple card, such as a Model 7057A, 7402, or 7014 installed in a Model 7001 or 7002 Switch System.

Connections

Figure 2-8
Thermocouple temperature measurements



Configuration

The following information explains the various configuration options for temperature measurements. To select and configure the thermocouple measurement:

Press SHIFT then TCOUPL. Three choices are available using the ▲ and ▼ keys:

- UNITS — C, K, F (Centigrade, Kelvin, Fahrenheit). This parameter selects the displayed units for temperature measurements.
- TYPE — J, K, T (thermocouple type).
- JUNC — SIM, CH1 (simulated or referenced at Channel 1). Typically, a thermocouple card uses a single reference junction. The Model 2000 can simulate a reference junction temperature or use the reference junction on a switching card. Typical reference junction temperatures are 0°C and 23°C.

A simulated reference temperature is the temperature of the junction where the thermocouple voltage is sensed. It is room temperature if the thermocouple wire is terminated to banana jacks and corrected directly to the multimeter. The accuracy of a temperature measurement depends on the accuracy of the reference junction.

Math

Model 2000 math operations are divided into four categories:

- mX+b and percent
- dBm and dB calculations
- Statistics of buffered readings
- Limit testing

The first two categories are discussed here; buffered reading statistics and reading limit testing are described in Section 3 — Measurement Options.

The procedure to select and configure a math operation is summarized as follows:

1. Press SHIFT then the appropriate math key.
2. Configure the parameters for the math operation. Press ENTER when done. (Press SHIFT then the related math function to end the calculation.)

NOTES *Once enabled for a function, the mX+b and percentage calculations are in effect across function changes.*

The Model 2000 uses IEEE-754 floating point format for math calculations.

MX + B

This math operation lets you manipulate normal display readings (X) mathematically according to the following calculation:

$Y = mX + b$

where: X is the normal display reading
m and b are user-entered constants for scale factor and offset
Y is the displayed result

Configuration

To configure the mX+b calculation, perform the following steps:

1. Press SHIFT then MX+B to display the present scale factor:

   M: +1.000000 ^
2. Enter a value and units prefix. Use the ◄ and ► keys to choose a numerical place and use the ▲ and ▼ keys to increment or decrement the digits.
3. Press ENTER to confirm the M value and display the B value:

   B: +00.00000 m
4. Enter a value and units prefix.
5. Press ENTER to confirm the B value and display the UNITS designation:

   MXB
6. Scroll through the letters to change and press ENTER when done.

The Model 2000 then displays the result of the calculation.

Percent

This item selects the percentage calculation and lets you specify a reference value. The displayed reading will be expressed as a percent deviation from the reference value. The percentage calculation is performed as follows:

$$\text{Percent} = \frac{\text{Input - Reference}}{\text{Reference}} \times 100\%$$

where: Input is the normal display reading.
Reference is the user entered constant.
Percent is the displayed result.

Configuration

To configure the percent calculation, perform the following steps:

1. Press SHIFT then % to display the present value:

   REF:+1.000000^
2. Enter a reference sign, value, and units prefix. Use the ◄ and ► keys to choose a numerical place and use the ▲ and ▼ keys to increment or decrement the digits.
3. Press ENTER when done.

The Model 2000 will display the result of the calculation. The result is positive when the input exceeds the reference and negative when the input is less than the reference. Engineering units are used to show values in the range 1 nano to 1000G. Exponential notation is used above that range.

dBm calculation

dBm is defined as decibels above or below a 1mW reference. With a user-programmable reference impedance, the Model 2000 reads 0dBm when the voltage needed to dissipate 1mW through the reference impedance is applied. The relationship between dBm, a reference impedance, and the voltage is defined by the following equation:

$$dBm = 10 \log \frac{\left(V_{IN}^2 / Z_{REF}\right)}{1mW}$$

Where: V_{IN} is the DC or AC input signal.
Z_{REF} is the specified reference impedance.

NOTE *Do not confuse reference impedance with input impedance. The input impedance of the instrument is not modified by the dBm parameter.*

If a relative value is in effect when dBm is selected, the value is converted to dBm then REL is applied to dBm. If REL is applied after dBm has been selected, dBm math has REL applied to it.

Configuration

To set the reference impedance, perform the following steps:

1. After selecting dBm, the present reference impedance is displayed (1-9999Ω):

   REF: 0000

2. To change the reference impedance, use the ◄ and ► keys to select the numeric position. Then use the ▲ and ▼ keys to select the desired value. Be sure to press ENTER after changing the reference impedance.

NOTES *dBm is valid for positive and negative values of DC volts.*

The mX+b and percent math operations are applied after the dBm or dB math. For example, if mX+b is selected with m=10 and b=0, the display will read 10.000 MXB for a 1VDC signal. If dBm is selected with Z_{REF} = 50Ω, the display will read 130MXB.

dB calculation

Expressing DC or AC voltage in dB makes it possible to compress a large range of measurements into a much smaller scope. The relationship between dB and voltage is defined by the following equation:

$$dB = 20 \log \frac{V_{IN}}{V_{REF}}$$

where: V_{IN} is the DC or AC input signal.
V_{REF} is the specified voltage reference level.

The instrument will read 0dB when the reference voltage level is applied to the input.

If a relative value is in effect when dB is selected, the value is converted to dB then REL is applied to dB. If REL is applied after dB has been selected, dB has REL applied to it.

Configuration

To set the reference voltage, perform the following steps:

1. After selecting dB, the present reference voltage level is displayed:

   REF: +0.000000

2. To change the reference level, use the ◄ and ► keys to select the numeric position. Then use the ▲ and ▼ keys to select the desired value. Be sure to press ENTER after changing the reference voltage.

NOTES *The dB calculation takes the absolute value of the ratio V_{IN} / V_{REF}*

The largest negative value of dB is -160dB. This will accommodate a ratio of V_{IN} = 1μV and V_{REF} = 1000V.

Measuring continuity

The Model 2000 uses the 1kΩ range to measure circuit continuity. After selecting continuity, the unit prompts you for a threshold resistance level (1Ω-1000Ω). The Model 2000 alerts you with a beep when a reading is below the set level.

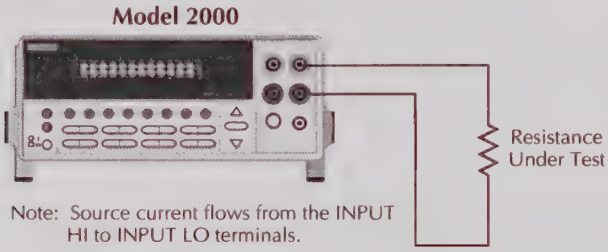
To measure the continuity of a circuit, press SHIFT then CONT, set the threshold resistance level and connect the circuit.

NOTE Continuity has a non-selectable reading rate of FAST (0.1 PLC).

Connections

Connect the circuit you want to test to the INPUT HI and INPUT LO terminals of the Model 2000. The test current flows from the INPUT HI as shown in Figure 2-9.

Figure 2-9
Continuity measurements



Threshold resistance level

You can define a threshold resistance from 1Ω to 1000Ω. The factory setting is 10Ω. Follow these steps to define the resistance level:

1. Press SHIFT then CONT.
2. Use the ◄ and ► keys to choose a numerical place and use the ▲ and ▼ keys to increment or decrement the digits. Enter a value from 1 to 1000.
3. Press ENTER to confirm your setting.

Testing diodes

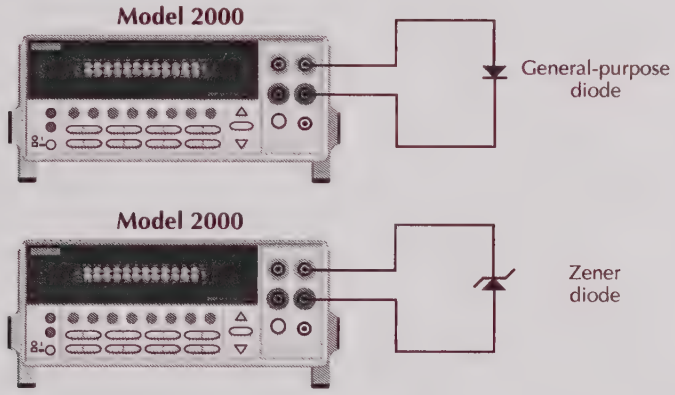
With a Model 2000, you can measure the forward voltage drop of general-purpose diodes and the zener voltage of zener diodes. To test diodes, press SHIFT then →|←, set the test current range, connect the diode, and take a reading from the display.

NOTE Diode test has a non-selectable reading rate of MEDium (1 PLC).

Connections

Connect the diode leads to the INPUT HI and INPUT LO terminals on the Model 2000. The test current flows from the INPUT HI terminal as shown in Figure 2-10.

Figure 2-10
Diode testing



Note: Source current flows from the INPUT HI to INPUT LO terminals.

Range

You can set the test current range from the front panel. The choices are 1mA, 100µA, and 10µA. The factory test current setting is 1mA. To set the test current, do following:

1. Press SHIFT then →|←.
2. Use the ▲ and ▼ keys to scroll through the three test current selections.

The diode test measures voltages on the 3V range for the 1mA test current and the 10V range for the 100µA and 10µA ranges. If a reading is more than 10V, the Model 2000 displays the "OVERFLOW" status message.

3
Measurement Options

Introduction

This section describes the front panel features of the Model 2000. For those measurement options accessible only by a remote interface, refer to Sections 4 and 5. This section is organized as follows:

- **Measurement configuration** — Describes ranging, filtering, relative readings, digits of resolution, and measurement rate.
- **Trigger operations** — Uses a trigger model to explain trigger modes and sources.
- **Buffer operations** — Discusses the reading storage buffer and buffer statistics.
- **Limit operations** — Defines how to set reading limits.
- **Scan operations** — Explains the internal and external scanning capabilities.
- **System operations** — Gives details on setup saving and restoring, selecting a remote interface, and accessing test and calibration.

Measurement configuration

The following paragraphs discuss configuring the multimeter for making measurements. See the end of Appendix A for information about optimizing readings for speed or accuracy.

Range

The selected measurement range affects both the ultimate digits and accuracy of the measurements as well as the maximum signal that can be measured. The range setting (fixed or auto) for each measurement function is saved when changing functions.

Maximum readings

The full scale readings for every range on each function are 20% overrange except for the 1000VDC, 750VAC, 3ADC, 3AAC, and diode test ranges.

Input values more than the maximum readings cause the "OVERFLOW" messages to be displayed.

Manual ranging

To select a range, simply press the RANGE ▲ or ▼ key. The instrument changes one range per keypress. The selected range is displayed for one second.

If the instrument displays the "OVERFLOW" message on a particular range, select a higher range until an on-range reading is displayed. Use the lowest range possible without causing an overflow to ensure best accuracy and resolution.

Note that the temperature and continuity functions have just one range.

Autoranging

To enable autoranging, press the AUTO key. The AUTO annunciator turns on when autoranging is selected. While autoranging is selected, the instrument automatically chooses the best range to measure the applied signal. Autoranging should not be used when optimum speed is required.

Note that up-ranging occurs at 120% of range, while down-ranging occurs at 10% of nominal range.

To cancel autoranging, press AUTO or the RANGE ▲ or ▼ key. Pressing AUTO to cancel autoranging leaves the instrument on the present range.

The AUTO key has no effect on the temperature, continuity, and diode test functions.

Filter

FILTER lets you set the filter response to stabilize noisy measurements. The Model 2000 uses a digital filter, which is based on reading conversions. The displayed, stored, or transmitted reading is simply an average of a number of reading conversions (from 1 to 100).

To select a filter:

1. Press FILTER once if the FILT annunciator is off; press twice if FILT is on.
2. Enter the number of readings.
3. Select the type of filter you want (moving average or repeating), then press ENTER.

The FILT annunciator turns on. When a filter is enabled, the selected filter configuration for that measurement function is in effect.

Pressing FILTER once disables the filter.

NOTE *The filter can be set for any measurement function except frequency, period, continuity, and diode test.*

Filter types

The moving average filter uses a first-in, first-out stack. When the stack becomes full, the measurement conversions are averaged, yielding a reading. For each subsequent conversion placed into the stack, the oldest conversion is discarded, and the stack is re-averaged, yielding a new reading.

For the repeating filter, the stack is filled and the conversions are averaged to yield a reading. The stack is then cleared and the process starts over. Choose this filter for scanning so readings from other channels are not averaged with the present channel.

Figure 3-1
Moving average and repeating filters

Response time

The filter parameters have speed and accuracy tradeoffs for the time needed to display, store, or output a filtered reading. These affect the number of reading conversions for speed versus accuracy and response to input signal changes.

Relative

The rel (relative) function can be used to null offsets or subtract a baseline reading from present and future readings. When rel is enabled, the instrument uses the present reading as a relative value. Subsequent readings will be the difference between the actual input value and the rel value.

You can define a rel value for each function. Once a rel value is established for a measurement function, the value is the same for all ranges. For example, if 50V is set as a rel value on the 100V range, the rel is also 50V on the 1000V, 10V, 1V, and 100mV ranges.

Thus, when you perform a zero correction for DCV, Ω2, and Ω4 measurements by enabling REL, the displayed offset becomes the reference value. Subtracting the offset from the actual input zeroes the display, as follows:

Actual Input – Reference = Displayed Reading

A rel value can be as large as the highest range.

Selecting a range that cannot accommodate the rel value does not cause an overflow condition, but it also does not increase the maximum allowable input for that range. For example, on the 10V range, the Model 2000 still overflows for a 12V input.

To set a rel (relative) value, press REL key when the display shows the value you want as the relative value. The REL annunciator turns on. Pressing REL a second time disables rel.

You can input a REL value manually using the mX+b function. Set M for 1 and B for any value you want. Pressing REL enables that value to be the relative value. See Section 2 for more information on the mX+b function.

Digits

The display resolution of a Model 2000 reading depends on the DIGITS setting. It has no effect on the remote reading format. The number of displayed digits does not affect accuracy or speed. Those parameters are controlled by the RATE setting.

Perform the following steps to set digits for a measurement function:

1. Press the desired function.
2. Press the DIGITS key until the desired number of digits is displayed (3½ to 6½).

NOTE *Frequency and period can be displayed with four to seven digits.*

Rate

The RATE operation sets the integration time of the A/D converter, the period of time the input signal is measured (also known as aperture). The integration time affects the usable digits, the amount of reading noise, as well as the ultimate reading rate of the instrument. The integration time is specified in parameters based on a number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec and 1 PLC for 50Hz and 400Hz is 20msec.

In general, the fastest integration time (FAST (0.1 PLC) from the front panel, 0.01 PLC from the bus) results in increased reading noise and fewer usable digits, while the slowest integration time (10 PLC) provides the best common-mode and normal-mode rejection. In-between settings are a compromise between speed and noise.

The RATE parameters are explained as follows:

- FAST sets integration time to 0.1 PLC. Use FAST if speed is of primary importance (at the expense of increased reading noise and fewer usable digits).
- MEDium sets integration time to 1 PLC. Use MEDium when a compromise between noise performance and speed is acceptable.
- SLOW sets integration time to 10 PLC. SLOW provides better noise performance at the expense of speed.

NOTE *The integration time can be set for any measurement function except frequency, period, continuity (FAST), and diode test (MEDium). For frequency and period, this value is gate time or aperture.*

For the AC functions, MEDium and SLOW have no effect on the number of power line cycles. See the discussion on "Bandwidth" that follows.

Bandwidth

The rate setting for AC voltage and current measurements determines the bandwidth setting:

- Slow — 3Hz to 300kHz.
- Medium — 30Hz to 300kHz.
- Fast — 300Hz to 300kHz.

Bandwidth is used to specify the lowest frequency of interest. When the Slow bandwidth (3Hz to 300kHz) is chosen, the signal goes through an analog RMS converter. The output of the RMS converter goes to a fast (1kHz) sampling A/D and the RMS value is calculated from 1200 digitized samples (1.2s).

When the Medium bandwidth (30Hz to 300kHz) is chosen, the same circuit is used. However, only 120 samples (120ms) are needed for an accurate calculation because the analog RMS converter has turned most of the signal to DC.

In the Fast bandwidth (300Hz to 300kHz), the output of the analog RMS converter (nearly pure DC at these frequencies) is simply measured at 1 PLC (16.6ms).

Table 3-1 lists the rate settings for the various measurement functions. The FAST, MED, and SLOW annunciators are only lit when conditions in the table are met. In other case, the annunciators are turned off.

Table 3-1
Rate settings for the measurement functions

Function	Rate		
	Fast	Medium	Slow
DCV, DCI	NPLC=0.1	NPLC=1	NPLC=10
ACV, ACI	NPLC=1, BW=300	NPLC=X, BW=30	NPLC=X, BW=3
Ω2W, Ω4W	NPLC=0.1	NPLC=1	NPLC=10
FREQ, PERIOD	APER=1s	APER=1s	APER=1s
dB, dBm (ACV)	NPLC=1, BW=300	NPLC=X, BW=30	NPLC=X, BW=3
dB, dBm (DCV)	NPLC=0.1	NPLC=1	NPLC=10
Continuity	NPLC=0.1	N/A	N/A
Diode test	N/A	NPLC=1	N/A

Notes:
NPLC = number of power line cycles.
BW = lower limit of bandwidth (in Hz).
APER = aperture in seconds.
N/A = not available.
X = setting ignored.

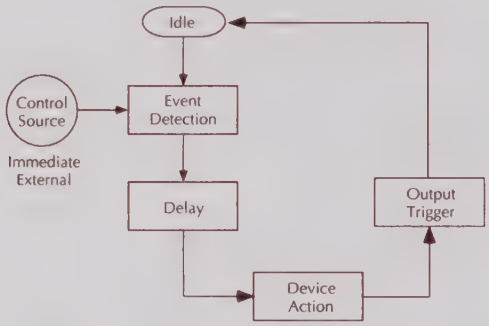
Trigger operations

The following paragraphs discuss front panel triggering, the programmable trigger delay, the reading hold feature, and external triggering.

Trigger model

The flowchart of Figure 3-2 summarizes triggering as viewed from the front panel. It is called a trigger model because it is modeled after the SCPI commands used to control triggering. Note that for stepping and scanning, the trigger model has additional control blocks. These are described in "Scan operations" later in this section.

Figure 3-2
Front panel triggering without stepping/scanning



Idle

The instrument is considered to be in the idle state whenever it is not performing any measurements or scanning functions. From the front panel, the unit is considered idle at the end of a step or scan operation when the reading for the last channel remains displayed. To restore triggers, use the SHIFT-HALT keys.

Once the Model 2000 is taken out of idle, operation proceeds through the flowchart.

Control source and event detection

The control source holds up operation until the programmed event occurs and is detected. The control sources are described as follows:

- Immediate — With this control source, event detection is immediately satisfied allowing operation to continue.
- External — Event detection is satisfied for any of three conditions:
  - An input trigger via the Trigger Link line EXT TRIG is received.
  - A bus trigger (GET or *TRG) is received.
  - The front panel TRIG key is pressed. (The Model 2000 must be taken out of remote before it will respond to the TRIG key. Use the LOCAL key or send LOCAL 716 over the bus.)

Delay

A programmable delay is available after event detection. It can be set manually or an auto delay can be used. With auto delay, the Model 2000 selects a delay based on the function and range. The AUTO settings are listed in Table 3-2.

Table 3-2
Auto delay settings

Function	Range and delay						
DCV	100mV	1V	10V	100V	1000V		
	1ms	1ms	1ms	5ms	5ms		
ACV	100mV	1V	10V	100V	750V		
	400ms	400ms	400ms	400ms	400ms		
FREQ	100mV	1V	10V	100V	750V		
	1ms	1ms	1ms	1ms	1ms		
DCI	10mA	100mA	1A	3A			
	2ms	2ms	2ms	2ms			
ACI			1A	3A			
			400ms	400ms			
Ω2W, Ω4W	100Ω	1kΩ	10kΩ	100kΩ	1MΩ	10MΩ	100MΩ
	3ms	3ms	13ms	25ms	100ms	150ms	250ms
Continuity		1kΩ					
		3ms					
Diode testing		1mA	100µA	10µA			
		1ms	1ms	1ms			

The delay function is accessed by pressing the SHIFT-DELAY keys. The present delay setting (AUTO or MANual) is displayed. Use the ▲ and ▼ keys to select the type of delay. If MANual is chosen, also enter the duration of the delay. The maximum is shown following:

99H:99M:99.999S

Press ENTER to accept the delay or EXIT for no change.

Changing the delay to MANual on one function changes the delays on all functions to MANual.

Device actions

The primary device action is a measurement. However, the device action block could include the following additional actions:

- Filtering — If the repeating filter is enabled, the instrument samples the specified number of reading conversions to yeildl single filtered reading. Only one reading conversion is performed if the filter is disabled, or after the specified number of reading conversions for a moving average filter is reached. The output of filter feeds hold.
- Hold — With hold enabled, the first processed reading becomes the "seed" reading and operation loops back within the device action block. After the next reading is processed, it is checked to see if it is within the selected window (0.01%, 0.1%, 1%, 10%) of the "seed" reading. If the reading is within the window, operation again loops back within the device action block. This looping continues until the specified number (2 to 100) consecutive readings are within the window. If one of the readings is not within the window, the instrument acquires a new "seed" reading and the hold process continues.
- Channel closure — When stepping or scanning, the last device action is to open the previous channel (if closed) and close the next channel. Using the hold feature provides an auto settling time for the scanner relays. Each open/close transition will restart the hold process and a reading for each channel will not occur until the relay settles.

Output trigger

After the device action, an output trigger occurs and is available at the rear panel Trigger Link connector. This trigger can be used to trigger another instrument to perform an operation (e.g., select the next channel for an external scan).

Counters

The trigger model for stepping and scanning contains additional blocks for counting samples (the number of channels to scan) and counting triggers. These counters are explained in the paragraph "Scan operations" later in this section.

Reading hold (autosettle)

When a hold reading is acquired as described in "Device actions", an audible beep is sounded (if enabled) and the reading is considered a "true measurement". The reading is held on the display until an "out of window" reading occurs to restart the hold process.

When operating remotely or scanning, the hold process seeks a new "seed""once it has been satisfied and the reading has been released. When operating from the front panel, the hold process does not seek a new "seed" until the held condition is removed.

Hold example

1. Enable HOLD, select a window percentage and enter a count.
2. Apply test probes to a signal. Once the signal becomes stable enough to satisfy the hold condition, the reading is released, and the beeper sounds (if enabled).
3. Remove the hold condition by lifting the probes. Hold will then seek a new "seed".

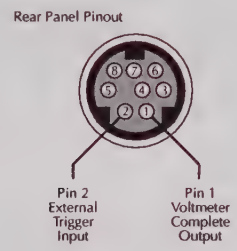
External triggering

The EXT TRIG key selects triggering from two external sources: trigger link and the TRIG key. When EXT TRIG is pressed, the TRIG annunciator lights and dashes are displayed to indicate that instrument is waiting for an external trigger. From the front panel, you can press the TRIG key to trigger a single reading. Pressing the EXT TRIG key again toggles you back to continuous triggers.

The Model 2000 uses two lines of the Trigger Link rear panel connector as External Trigger (EXT TRIG) input and Voltmeter Complete (VMC) output. The EXT TRIG line allows the Model 2000 to be triggered by other instruments. The VMC line allows the Model 2000 to trigger other instruments.

At the factory, line 1 is configured as VMC and line 2 as EXT TRIG. (Changing this configuration is described in the optional Model 2000 Repair Manual.) A connector pinout is shown in Figure 3-3.

Figure 3-3
Rear panel pinout



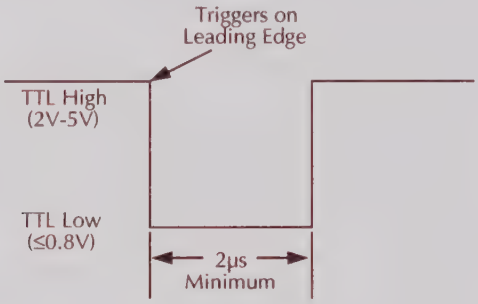
Pin Number	Description
1	Voltmeter Complete Output
2	External Trigger Input
3	no connection *
4	no connection *
5	no connection *
6	no connection *
7	Signal Ground
8	Signal Ground

* Either pin 3 or 5 may be configured as an output instead of pin 1. Either pin 4 or 6 may be configured as an input instead of pin 2. See the optional Model 2000 Repair Manual for details.

External trigger

The EXT TRIG input requires a falling-edge, TTL-compatible pulse with the specifications shown in Figure 3-4. In general, external triggers can be used to control measure operations. For the Model 2000 to respond to external triggers, the trigger model must be configured for it.

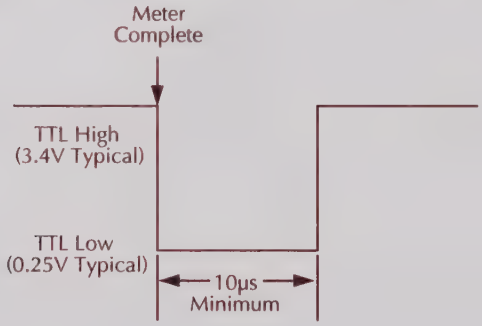
Figure 3-4
Trigger link input pulse specifications (EXT TRIG)



Voltmeter complete

The VMC output provides a TTL-compatible output pulse that can be used to trigger other instruments. The specifications for this trigger pulse are shown in Figure 3-5. Typically, you would want the Model 2000 to output a trigger after the settling time of each measurement.

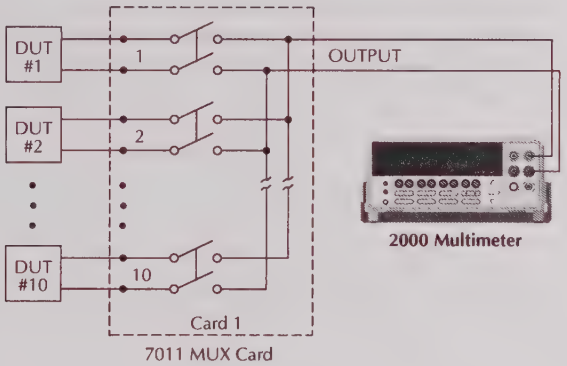
Figure 3-5
Trigger link output pulse specifications (VMC)



External triggering example

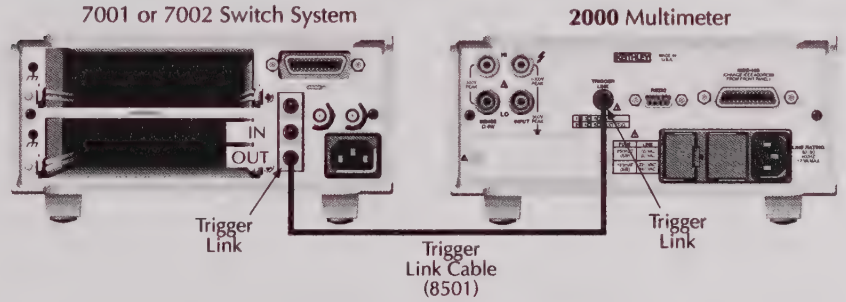
In a typical test system, you may want to close a channel and then measure the DUT connected to the channel with a multimeter. Such a test system is shown in Figure 3-6, which uses a Model 2000 to measure ten DUTs switched by a Model 7011 multiplexer card in a Model 7001/7002 Switch System.

Figure 3-6
DUT test system



The Trigger Link connections for this test system are shown in Figure 3-7. Trigger Link of the Model 2000 is connected to Trigger Link (either IN or OUT) of the Model 7001/7002. Note that with the default trigger settings on the Model 7001/7002, line #1 is an input and line #2 is an output. This complements the trigger lines on the Model 2000.

Figure 3-7
Trigger link connections



For this example, the Model 2000 and 7001/7002 are configured as follows:

Model 2000:

Factory defaults restored (accessed from SHIFT-SETUP)
External scanning, channels 1 - 10, no timer, 10 readings (accessed from SHIFT-CONFIG)
External triggers (accessed from EXT TRIG)

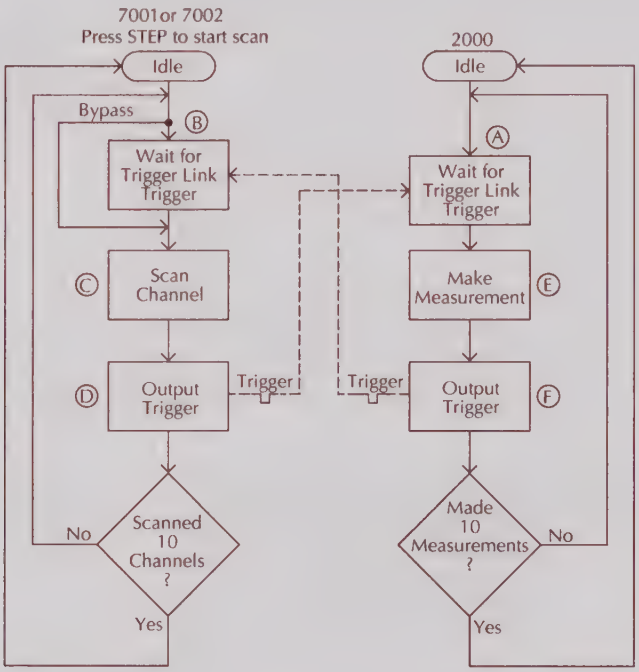
Model 7001 or 7002:

Factory defaults restored
Scan list = 1!1-1!10,
Number of scans = 1
Channel spacing = TrigLink

To run the test and store readings in the Model 2000 with the unit set for external triggers, press STEP or SCAN. The Model 2000 waits (with the asterisk annunciator lit) for an external trigger from the Model 7001/7002.

Press STEP on the Model 7001/7002 to take it out of idle and start the scan. The scanner's output pulse triggers the Model 2000 to take a reading, store it, and send a trigger pulse. The following explanation on operation is referenced to the operation model shown in Figure 3-8.

Figure 3-8
Operation model for triggering example



Ⓐ Pressing EXT TRIG then STEP or SCAN on the multimeter places it at point A in the flowchart, where it is waiting for an external trigger.

Ⓑ Pressing STEP takes the Model 7001/7002 out of the idle state and places operation at point B in the flowchart.

Ⓒ For the first pass through the model, the scanner does not wait at point B for a trigger. Instead, it closes the first channel.

Ⓓ After the relay settles, the Model 7001/7002 outputs a Channel Ready pulse. Since the instrument is programmed to scan ten channels, operation loops back up to point B, where it waits for an input trigger.

Ⓔ and Ⓕ Remember that the Model 2000 operation is at point A waiting for a trigger. The output Channel Ready pulse from the Model 7001/7002 triggers the multimeter to measure DUT #1 (point E). After the measurement is complete, the Model 2000 outputs a completion pulse (point F) and then loops back to point A, where it waits for another input trigger.

The trigger applied to the Model 7001/7002 from the Model 2000 closes the next channel in the scan. This triggers the multimeter to measure the next DUT. The process continues until all ten channels are scanned and measured.

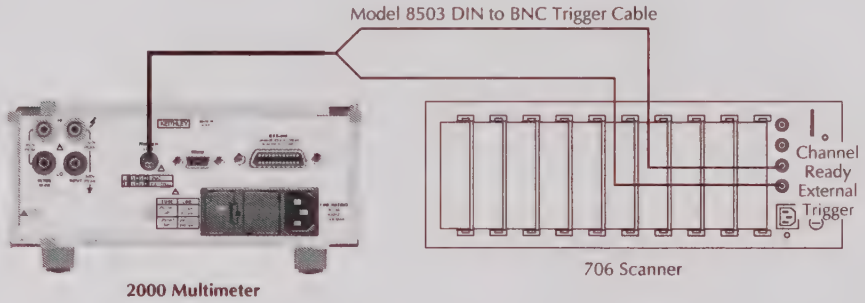
External triggering with BNC connections

An adapter cable is available to connect the micro-DIN Trigger Link of the Model 2000 to instruments with BNC trigger connections. The Model 8503 DIN to BNC Trigger Cable has a micro-DIN connector at one end and two BNC connectors at the other end. The BNC cables are labeled VMC (trigger line 1) and EXT TRIG (trigger line 2).

Figure 3-9 shows how a Keithley Model 706 Scanner can be connected to the Trigger Link of the Model 2000 using the adapter cable. With this adapter, a Model 706 could be substituted for the Model 7001/7002 in the previous example. With the Model 706 set for External Triggering, the test would start when the single scan mode is selected and initiated.

If the Model 2000 trigger line configuration has been changed from the factory setting, the Model 8502 Trigger Link Adapter must be used to interface with instruments having BNC trigger connections. It has two micro-DIN connectors and six BNC connectors, one for each trigger line.

Figure 3-9
DIN to BNC trigger cable



Buffer operations

The Model 2000 has a buffer to store from two to 1024 readings and units. It also stores the channel number for scanned readings and overflow readings. In addition, recalled data includes statistical information, such as minimum, maximum, average, and standard deviation.

The buffer fills with the requested number of readings and stops. Readings are placed in the buffer after any math operations are performed. Buffered data is overwritten each time the storage operation is selected. The data is volatile; it is not saved through a power cycle.

The following paragraphs discuss storing and recalling buffered data.

Storing readings

Use the following procedure to store readings:

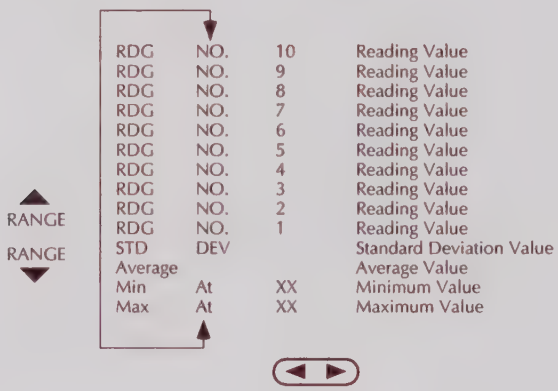
1. Set up the instrument for the desired configuration.
2. Press the STORE key.
3. Using the ◄ , ► , ▲, and ▼ keys to select the number of readings desired.
4. Press ENTER. The asterisk (*) annunciator turns on to indicate a data storage operation. It will turn off when the storage is finished.

Recalling readings

Use the following steps to view stored readings and buffer statistics:

1. Press RECALL. The BUFFER annunciator indicates that stored readings are being displayed. The arrow annunciator indicates that more data can be viewed with the ◄ , ► , ▲, and ▼ keys.
2. As shown in Figure 3-10, use the cursor keys to navigate through the reading numbers, reading values, and statistics. For any of the buffer statistics (maximum, minimum, average, statndard deviation), the STAT annunciator is on.
3. Use the EXIT key to return to the normal display.

Figure 3-10
Buffer locations


RANGE
RANGE
RDG NO. 10 Reading Value
RDG NO. 9 Reading Value
RDG NO. 8 Reading Value
RDG NO. 7 Reading Value
RDG NO. 6 Reading Value
RDG NO. 5 Reading Value
RDG NO. 4 Reading Value
RDG NO. 3 Reading Value
RDG NO. 2 Reading Value
RDG NO. 1 Reading Value
STD DEV Standard Deviation Value
Average Average Value
Min At XX Minimum Value
Max At XX Maximum Value

Buffer statistics

The MAX AT and MIN AT values are the maximum and minimum values in the buffer. The AVERAGE value is the mean of the buffered readings. The equation used to calculate the mean is:

$$y = \frac{\sum_{i=1}^{n} X_i}{n}$$

where: x_i is a stored reading
n is the number of stored readings

The STD DEV value is the standard deviation of the buffered readings. The equation used to calculate the standard deviation is:

$$y = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - \left(\frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2\right)}{n-1}}$$

where: x_i is a stored reading
n is the number of stored readings

NOTE *The Model 2000 uses IEEE-754 floating point format for math calculations.*

Limit operations

Limit operations set and control the values that determine the HI / IN / LO status of subsequent measurements. Limits can be applied to all measurement functions except continuity. The limit test is performed after mX+b and percent math operations. Unit prefixes are applied before the limit test, for example:

- Low limit = -1.0, High limit = 1.0
  A 150mV reading equals 0.15V (IN).
- Low limit = -1.0, High limit = 1.0
  A 0.6kΩ reading equals 600Ω (HI).

You can configure the multimeter to beep or not when readings are inside or outside of the limit range.

Setting limit values

Use the following steps to enter high and low limit values:

1. Press the SHIFT-LIMITS keys to view the present HI limit value:

   HI:+1.000000 ^

   This value represents the absolute value of that function.

2. Use the ◄ , ► , ▲, and ▼ keys to enter the desired value. Move the cursor to the rightmost position and use the ▲ and ▼ keys to move the decimal point.
3. Press ENTER to view the present LO limit value:

   LO:-1.000000 ^

   This value represents the absolute value of that function.

4. Enter the desired value for the low limit. Pressing ENTER returns to the normal display.

Enabling limits

Use the following procedure to turn on the limits operation:

1. Press the SHIFT-ON/OFF keys to view the present beeper status:

   BEEP: NEVER

2. Use the ▲ and ▼ keys to change the beeper status (NEVER, OUTSIDE, INSIDE). Press ENTER when done.

When the multimeter returns to the normal display, the HI/IN/LO status is displayed along with the reading. To disable limit testing, press SHIFT-ON/OFF again. An example of using limits to sort resistors is shown in Figure 3-11.

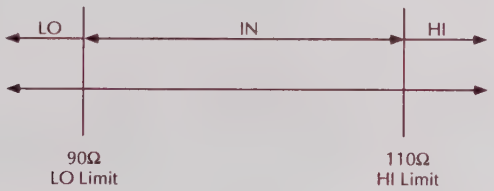


Figure 3-11
Using limit test to sort 100Ω, 10% resistors

Scan operations

The Model 2000 can be used with an internal scanner card (Model 2000 SCAN or 2001-TCSCAN) or with external scanner cards installed in switching mainframes such as the Models 707, 7001, and 7002. The following paragraphs discuss various aspects of using scanning with the Model 2000.

Connection precautions

WARNINGS **Connection information for scanner cards is intended for qualified service personnel. Do not attempt to connect the DUT or external circuitry to a scanner card unless qualified to do so.**

To prevent electric shock that could result in serious injury or death, adhere to the following safety precautions:

- **Before making or breaking connections to the scanner card, make sure the Model 2000 power is turned off and power is removed from all external circuitry.**
- **Do not connect signals that will exceed the maximum specifications of the scanner card.**

If both the front panel terminals and the scanner card terminals are connected at the same time, the maximum signal ratings of the front panel terminals are reduced to the maximum signal ratings of the scanner card.

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, scanner cards are Installation Category I and must not be connected to mains.

Scanning overview

A scanner lets you switch among a number of input signals to the Model 2000 for measurement. The channel control and scanning capabilities depend on whether an internal or external card is being used, as well as on the capabilities of the scanner card. Refer to the documentation supplied with the scanner card for specific connection information.

Using an internal scanner card

The optional Model 2000-SCAN scanner card lets you step through or scan up to ten 2-pole channels or five 4-pole channels.

The optional Model 2001-TCSCAN Thermocouple/General Purpose Scanner Card lets you multiplex one of nine 2-pole or one of four 4-pole analog signals into the Model 2000, and/or any combination of 2- or 4-pole analog signals.

Using external scanner cards

When using external channels, the switching mainframe controls the opening and closing of individual channels. To synchronize Model 2000 measurements with external channel closures, connect the Trigger Link lines of the multimeter and switching mainframe. Refer to "Trigger operations" earlier in this section for details and an example on using external triggering.

Front panel scanner controls

In addition to the trigger keys discussed previously, front panel keys that affect scanner card operation include:

- ◄ and ► — Allow you to manually step through consecutive internal card channels.
- OPEN and CLOSE — Let you selectively open and close internal card channels.
- SHIFT-CONFIG — Selects internal or external scanning, scan list, time between scans, and reading count.
- STEP — Starts a stepping operation of consecutive channels, where output triggers are sent after every channel closure.
- SCAN — Starts a scanning operation of consecutive channels, where an output trigger is sent at the end of the scan list.
- SHIFT-HALT — Stops stepping or scanning and restores the trigger model to a non-scanning mode.

Using ◄ and ► keys

The ◄ and ► keys can be used to manually scan through channels on the internal scanner card. With a scanner card installed in the option slot, press the ► key to manually increment channels or the ◄ key to manually decrement channels. The annunciator of the closed channel is lit. Hold down either key to manually scan through channels continuously. Press OPEN to open all channels.

Using OPEN and CLOSE keys

The OPEN and CLOSE keys control channels on the internal scanner card only. The keys allow you to directly:

- Close a specific channel (or channel pair for 4-wire resistance).
- Immediately open any internal closed channel (or channel pair for 4-wire resistance).

With a scanner card installed in the option slot of the Model 2000, the following prompt is displayed when the CLOSE key is pressed:

CLOSE CHAN:01

Use the ◄ , ► , ▲, and ▼ keys to display the desired channel (1 to 10) and press ENTER. The annunciator of the closed channel will be displayed on the front panel along with normal readings. Selecting a different channel from the one that is presently closed will cause the closed channel to open and allow a settling time before closing the selected channel.

Channel relays will be closed according to the presently selected function. If a 4-wire function is selected, both the selected channel relay and the matching relay pair will be closed. Fixed 4-pole relay pairs are:

- 1 and 6 (not available for Model 2001-TCSCAN)
- 2 and 7
- 3 and 8
- 4 and 9
- 5 and 10

Pressing the OPEN key will immediately open any closed scanner card channel or channel pair for 4-wire resistance.

Stepping and scanning trigger model additions

The trigger model presented in "Trigger operations" earlier in this section has some additional capabilities when stepping or scanning. These are outlined below:

- Timer — With this control source, event detection is immediately satisfied on the initial pass. Each subsequent detection is satisfied when the programmed timer interval (up to 99H:99M:99.99S) elapses.
- Reading counter — For both stepping and scanning, the reading count can be entered from SHIFT-CONFIG. (This is referred to as the trigger counter over the bus.) The reading counter can bypass the idle state. Operation will wait until the programmed control source event occurs.
- Channel counter — For scanning, the scan list length (maximum channel less minimum channel) is used to bypass the control source allowing a specified number of device actions to occur. (This counter is referred to as the sample counter over the bus.)

These additional blocks are shown in the trigger models of Figures 3-12 and 3-13. Uses of the timer control source, reading counter, and channel counter are shown in the scanning examples later in this section.

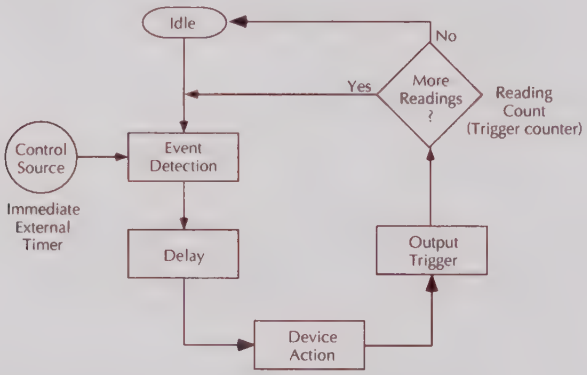


Figure 3-12
Front panel triggering with stepping

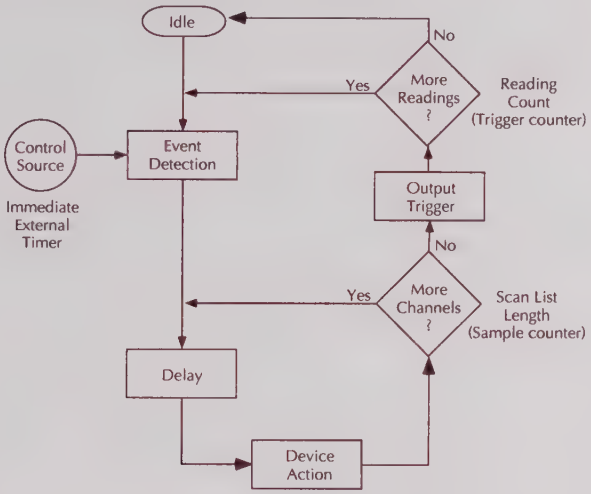


Figure 3-13
Front panel triggering with scanning

Using SHIFT-CONFIG to configure stepping and scanning

From the SHIFT-CONFIG key combination, you can select internal or external scanning, the minimum and maximum channels in the scan list, the time between scans, and the reading count.

1. To configure stepping or scanning, perform the following:
2. Select the desired measurement function.
3. Press the SHIFT-CONFIG keys to access the step/scan configuration.
4. Select the type of scan (INTernal or EXTernal) by using the ▲ and ▼ keys and pressing ENTER.
5. Select the first channel in the scan list (MINimum CHANnel) by using the ◄ , ► , ▲, and ▼ keys and pressing ENTER.
6. Select the last channel in the scan list (MAXimum CHANnel) and press ENTER to confirm.
7. The next selection is for timed scans. (This is the Timer control source in the trigger model.) It sets a user-specified interval for starting scans. If you choose timed scans, the Model 2000 prompts for a time interval:

   00H:00M:00.000S

   Use the ◄ , ► , ▲, and ▼ keys to select a time interval and press ENTER to confirm.

8. Next, you are prompted for a reading count (RDG CNT). This can be less than, equal to, or greater than the scan list length (up to 1024). It is the number of readings that will be stored in the buffer. The effects of these choices are further described in the scanning examples.
9. Press ENTER when done to return to the normal display. Note that scanned readings are always stored in the buffer, up to the setting for RDG CNT.

Scanning examples

The following examples demonstrate the use of reading count, timed scans, delay, and external scanning.

Counters

One of the configuration options for stepping and scanning is the reading count. The example of Figure 3-14 shows how different settings of RDG CNT affect these operations:

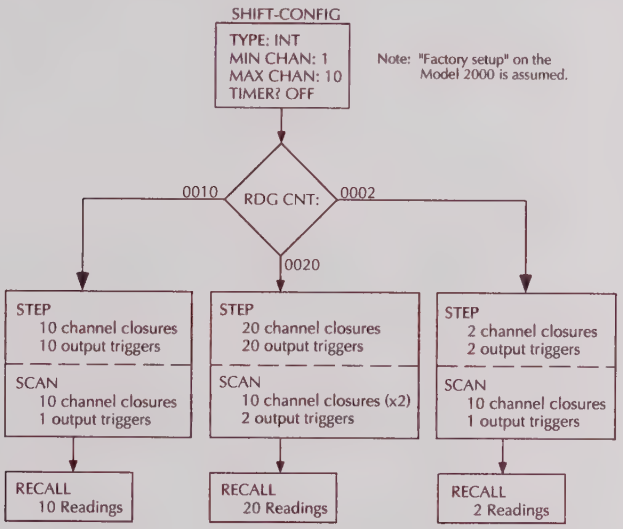


Figure 3-14
Internal scanning example with reading count option

- With a reading count (0010) equal to the scan list length (10), a step operation consecutively closes ten channels and sends an output trigger after each channel. A scan operation also consecutively closes ten channels but sends an output trigger only at the end of the scan.
- With a reading count (0020) greater than the scan list length (10), stepping yields 20 channel closures and 20 output triggers. Scanning also goes through the scan list twice but sends an output trigger only at the end of each scan.
- With a reading count (0002) less than the scan list length (10), stepping yields two channel closures and output triggers. Scanning goes through the entire scan list and sends an output trigger but only two readings are stored.

NOTE *If the reading count divided by the scan list length is not an integer, it is rounded up. For example, if the reading count is 15 and the scan list length is 10, there will be two output triggers for scanning.*

The differences between stepping and scanning counters for bus commands are summarized in Table 3-3.

Table 3-3
Bus commands parameters for stepping and scanning counters

Operation	:SAMPle:COUNt	:TRIGger:COUNt
STEP	1	reading count
SCAN	scan list length	(reading count) / (scan list length)

Timing

Another configuration option for stepping and scanning is the timing of channel closures. The example of Figure 3-15 shows how different settings of TIMER and DELAY affect these operations. These are the Timer control source and the Delay block shown in the trigger models of Figures 3-12 and 3-13.

- With the timer ON and set to five seconds and delay set to AUTO, channels are stepped through at five-second intervals with an output trigger after each closure. A scan operation yields ten channels scanned immediately with an output trigger at the end of the scan.
- With the timer OFF and the delay set to MANual for five seconds, stepping and scanning through the channels is timed the same. The difference is in the number of output triggers, with stepping sending a trigger after each channel closure and scanning sending a trigger at the end of the scan.

When using both the timer and delay parameters, the timer is not started until after the delay. For example, if the timer is two minutes and the delay is ten seconds, the timer is not started until 10sec after pressing SCAN. Each successive scan will occur at 2:10.0, 4:10.0, etc.

If the total delay time per scan is greater than or equal to the timer setting, the timer condition is already satisfied and, effectively, is ignored.

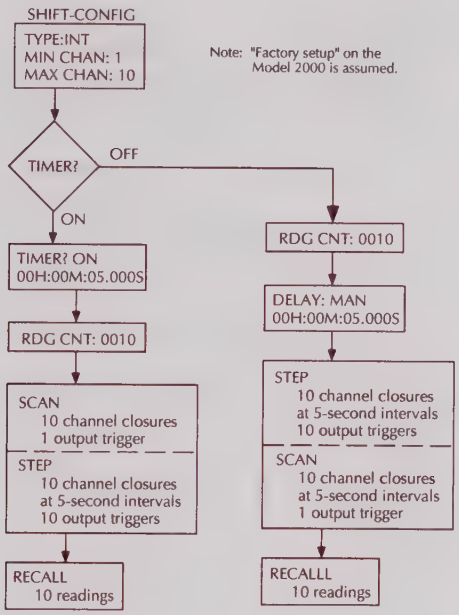


Figure 3-15
Internal scanning example with timer and delay options

External scanning

The example of Figure 3-16 shows the front panel operations to configure an external scan. The trigger and signal connections were shown previously in "Trigger operations". Both instrument setups assume factory defaults. Set the Model 2000 for the desired measurement function.

(1) On the Model 7001 Switch System, enter a scan list of channels 1 to 10 on card 1.

(2) Also on the Model 7001, configure the instrument for Trigger Link triggers and one scan of ten channels.

(3) On the Model 2000 Multimeter, configure an external scan of the first ten channels.

(4) Set the Model 2000 for external triggers by pressing EXT TRIG. The display will be dashes.

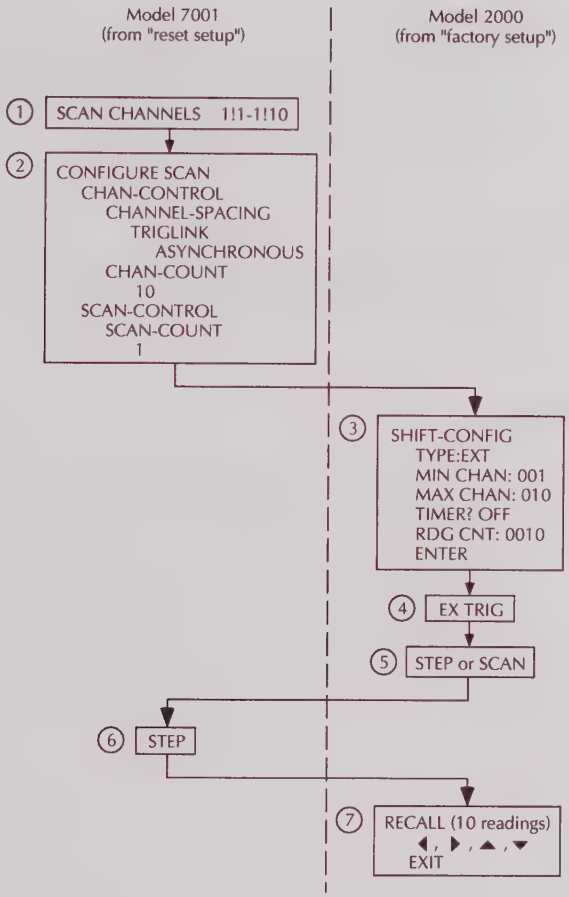
(5) Press STEP or SCAN on the Model 2000. The asterisk and STEP or SCAN annunciator will light.

(6) Press STEP on the Model 7001 to start channel closures.

(7) After the scan, you can recall ten readings from the Model 2000 buffer.

NOTE *When using an external thermocouple scanner card and channel 1 as a reference, the Model 2000 only recognizes channel 1 when a step or scan is performed. If using a Model 7001 or 7002 to close channel 1 manually, the Model 2000 will not interpret that channel as the reference junction without a step or scan operation.*

Figure 3-16
External scanning example with Model 7001



System operations

The Model 2000 has other front panel operations. Saving and restoring setup information is described in Section 2 — Basic Measurements. Selecting the remote interface and language is covered in Section 4 — Remote Operation.

Self-test

The TEST selections are used as diagnostic tools to isolate problems within the Model 2000. Information on using these test procedures is included in the optional Model 2000 Repair Manual.

Calibration

The CAL selections are used to view the calibration date and next due date, to perform calibration, and to view the number of times calibration has been performed. Some of the items are password-protected to prevent unintended changing of calibration constants.

To view the calibration dates, press SHIFT-CAL. Press ENTER at the DATES prompt. The first date is the last time calibration was performed. The NDUE date is the calibration due date.

Running calibration is password-protected. Refer to the Model 2000 Calibration Manual for details.

To view the calibration count, press ENTER at the COUNT prompt.

4
Remote Operation

Introduction

This section includes the following information:

- Selecting an interface
- Selecting a language
- RS-232 operation
- GPIB bus operation and reference
- Status structure
- Trigger model (GPIB operation)
- Programming syntax
- Common commands

Selecting an interface

The Model 2000 multimeter supports two built-in remote interfaces:

- GPIB bus
- RS-232 interface

You can use only one interface at a time. The factory interface selection is the GPIB bus. You can select the interface only from the front panel. The interface selection is stored in non-volatile memory; it does not change when power has been off or after a remote interface reset.

Before you select a remote interface, consider the programming language you want to use. For more information about selecting programming languages, see this section.

RS-232

You can connect a controller to the RS-232 interface. Some considerations for selecting the RS-232 interface are the following:

- You must define the baud rate, enable or disable software handshake XON/XOF.
- You can only use the SCPI programming language with the RS-232 interface.

To select RS-232 as the remote interface, do the following:

1. Access the RS-232 configuration by pressing SHIFT then RS232.

   You see: `RS232: OFF`

2. Move to the on/off selection by pressing the ► key.

   You see `OFF` selection blinking.

3. Turn on the RS-232 interface by toggling the selection to ON using the ▼ or ▲ key and press ENTER.

You can exit the configuration menu by pressing EXIT.

For more information about the RS-232 interface, see section RS-232 operation.

GPIB bus

The GPIB bus is the IEEE-488 interface. You must select a unique address for the Model 2000 multimeter. The address is displayed when the multimeter is turned on. At the factory, the address is set to 16.

Since GPIB is the interface selection defined by the factory, only follow these steps to select the GPIB interface if you have been previously using the RS-232 remote programming interface:

1. Select the GPIB option by pressing SHIFT then GPIB.

   You see: GPIB: OFF

2. Move to the on/off selection by pressing the ► key.

   You see `OFF` selection blinking slowly.

3. Turn on the GPIB interface by toggling the selection to ON using the ▼ or ▲ key and press ENTER.

Turning off the RS-232 interface automatically selects GPIB as the remote programming interface.

RS-232 operation

Sending and receiving data

The RS-232 interface transfers data using 8 data bits, 1 stop bit, and no parity. Make sure the controller you connect to the multimeter also uses these settings.

You can break data transmissions by sending a ^C or ^X character string to the multimeter. This clears any pending operation and discards any pending output.

Selecting baud rate

The baud rate is the rate at which the Model 2000 multimeter and the programming terminal communicate. Choose one these available rates:

- 19.2k
- 9600
- 4800
- 2400
- 1200
- 600
- 300

The factory selected baud rate is 4800.

When you choose a baud rate, make sure that the programming terminal that you are connecting to the Model 2000 multimeter can support the baud rate you selected. Both the multimeter and the other device must be configured for the same baud rate. To select a baud rate, follow these steps:

1. Access the RS-232 configuration by pressing SHIFT then RS232.

   You see: RS232: ON (assuming you have already selected the RS-232 interface)

2. Go to the baud rate field by pressing the ▼ key.

   You see `BAUD:<rate>`.

3. Access the baud rate list by pressing the ► key. You see the rate selection blinking.
4. Scroll through the available rates by pressing the ▼ and ▲ key until you find the rate you want.
5. Confirm your selection by pressing ENTER. The multimeter prompts you to define signal handshaking. Continue on for information about handshaking. You can return to measurement mode by pressing EXIT.

Selecting signal handshaking (flow control)

Signal handshaking between the controller and the instrument allows the two devices to communicate to each other regarding being ready or not ready to receive data. The Model 2000 does not support hardware handshaking (flow control).

Software flow control is in the form of X__ON and X__OFF characters and is enabled when XonXoFF is selected from the RS232 FLOW menu. When the input queue of the Model 2000 becomes more than 3/4 full, the instrument issues an X_OFF command. The control program should respond to this and stop sending characters until the Model 2000 issues the X_ON, which it will do once its input buffer has dropped below half-full. The Model 2000 recognizes X_ON and X_OFF sent from the controller. An X_OFF will cause the Model 2000 to stop outputting characters until it sees an X_ON. Incoming commands are processed after the <CR> character is received from the controller.

If NONE is the selected flow control, then there will be no signal handshaking between the controller and the Model 2000. Data will be lost if transmitted before the receiving device is ready.

Perform the following steps to set flow control:

1. Access the RS-232 configuration by pressing SHIFT and then RS232. You see: RS 232: ON (assuming you have already selected the RS-232 interface).
2. Go to the flow control field by using the ▲ or ▼ key. You see FLOW: <control>.
3. Access the flow control options by pressing the ► key. You see the flow control selection blinking.
4. Use the ▲ or ▼ key to display the desired flow control (NONE or XonXoFF) and press ENTER. You will then be prompted to set the terminator. Continue on for information about the terminator. You can return to the measurement mode by pressing EXIT.

Setting terminator

The Model 2000 can be configured to terminate each program message that it transmits to the controller with any combination of <CR> and <LF>. Perform the following steps to set the terminator:

1. Access the RS-232 configuration by pressing SHIFT and then RS232.

   You see: RS 232: ON (assuming you have already selected the RS-232 interface).

2. Go to the terminator field by using the ▲ or ▼ key.

   You see TX TERM: <terminator>.

3. Access the terminator options by pressing the ► key.

   You see the terminator selection blinking.

4. Use the ▲ or ▼ key to display the desired terminator (LF, CR or LFCR) and press ENTER. The instrument will return to the measurement mode.

RS-232 operation

Sending and receiving data

The RS-232 interface transfers data using 8 data bits, 1 stop bit, and no parity. Make sure the controller you connect to the multimeter also uses these settings.

You can break data transmissions by sending a ^C or ^X character string to the multimeter. This clears any pending operation and discards any pending output.

Selecting baud rate

The baud rate is the rate at which the Model 2000 multimeter and the programming terminal communicate. Choose one these available rates:

- 19.2k
- 9600
- 4800
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- 1200
- 600
- 300

The factory selected baud rate is 4800.

When you choose a baud rate, make sure that the programming terminal that you are connecting to the Model 2000 multimeter can support the baud rate you selected. Both the multimeter and the other device must be configured for the same baud rate. To select a baud rate, follow these steps:

1. Access the RS-232 configuration by pressing SHIFT then RS232.

   You see: RS232: ON (assuming you have already selected the RS-232 interface)

2. Go to the baud rate field by pressing the ▼ key.

   You see `BAUD:<rate>`.

3. Access the baud rate list by pressing the ▶ key. You see the rate selection blinking.
4. Scroll through the available rates by pressing the ▼ and ▲ key until you find the rate you want.
5. Confirm your selection by pressing ENTER. The multimeter prompts you to define signal handshaking. Continue on for information about handshaking. You can return to measurement mode by pressing EXIT.

Selecting signal handshaking (flow control)

Signal handshaking between the controller and the instrument allows the two devices to communicate to each other regarding being ready or not ready to receive data. The Model 2000 does not support hardware handshaking (flow control).

Software flow control is in the form of X__ON and X__OFF characters and is enabled when XonXoFF is selected from the RS232 FLOW menu. When the input queue of the Model 2000 becomes more than 3/4 full, the instrument issues an X_OFF command. The control program should respond to this and stop sending characters until the Model 2000 issues the X_ON, which it will do once its input buffer has dropped below half-full. The Model 2000 recognizes X_ON and X_OFF sent from the controller. An X_OFF will cause the Model 2000 to stop outputting characters until it sees an X_ON. Incoming commands are processed after the <CR> character is received from the controller.

If NONE is the selected flow control, then there will be no signal handshaking between the controller and the Model 2000. Data will be lost if transmitted before the receiving device is ready.

Perform the following steps to set flow control:

1. Access the RS-232 configuration by pressing SHIFT and then RS232. You see: RS 232: ON (assuming you have already selected the RS-232 interface).
2. Go to the flow control field by using the ▲ or ▼ key. You see FLOW: <control>.
3. Access the flow control options by pressing the ► key. You see the flow control selection blinking.
4. Use the ▲ or ▼ key to display the desired flow control (NONE or XonXoFF) and press ENTER. You will then be prompted to set the terminator. Continue on for information about the terminator. You can return to the measurement mode by pressing EXIT.

Setting terminator

The Model 2000 can be configured to terminate each program message that it transmits to the controller with any combination of <CR> and <LF>. Perform the following steps to set the terminator:

1. Access the RS-232 configuration by pressing SHIFT and then RS232.

   You see: RS 232: ON (assuming you have already selected the RS-232 interface).

2. Go to the terminator field by using the ▲ or ▼ key.

   You see TX TERM: <terminator>.

3. Access the terminator options by pressing the ► key.

   You see the terminator selection blinking.

4. Use the ▲ or ▼ key to display the desired terminator (LF, CR or LFCR) and press ENTER. The instrument will return to the measurement mode.

RS-232 connections

The RS-232 serial port can be connected to the serial port of a controller (i.e., personal computer) using a straight through RS-232 cable terminated with DB-9 connectors. **Do not use a null modem cable.** The serial port uses the transmit (TXD), receive (RXD) and signal ground (GND) lines of the RS-232 standard. It does not use the hardware handshaking lines CTS and RTS. Figure 4-1 shows the rear panel connector for the RS-232 interface, and Table 4-2 shows the pinout for the connector.

If your computer uses a DB-25 connector for the RS-232 interface, you will need a cable or adapter with a DB-25 connector on one end and a DB-9 connector on the other, wired straight through (not null modem).

Figure 4-1
RS-232 interface connector

Rear Panel Connector

Table 4-2
RS-232 connector pinout

Pin number	Description
1	no connection
2	TXD, transmit data
3	RXD, receive data
4	no connection
5	GND, signal ground
6	no connection
7	CTS, clear to send[1]
8	RTS, ready to send[1]
9	no connection

[1]CTS and RTS signals are not used.

Error messages

See Appendix B for RS-232 error messages.

GPIB bus operation and reference

Introduction

This section contains information about connecting to and using the GPIB (IEEE-488) bus. The information is organized as follows:

- GPIB bus standards
- GPIB bus connections
- Selecting the primary address
- QuickBASIC 4.5 programming
- General bus commands
- Front panel GPIB operation

GPIB bus standards

The GPIB bus is the IEEE-488 instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975. The Model 2000 multimeter conforms to these standards:

- IEEE-488-1987.1
- IEEE-488-1987.2

This standard defines a syntax for sending data to and from instruments, how an instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands.

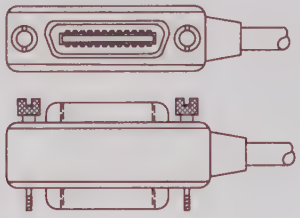
- SCPI 1991 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step farther than IEEE-488-1987.2 and defines a standard set of commands to control every programmable aspect of an instrument.

GPIB bus connections

To connect the Model 2000 multimeter to the GPIB bus, use a cable equipped with standard IEEE-488 connectors as shown in Figure 4-2.

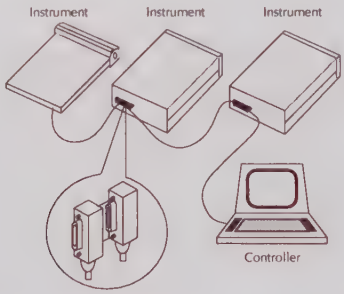
Figure 4-2
IEEE-488 connector



To allow many parallel connections to one instrument, stack the connector. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark-colored screws. Earlier versions had different screws, which were silver-colored. Do not use these types of connectors on the Model 2000 multimeter, because it is designed for metric threads.

Figure 4-3 shows a typical connecting scheme for a multi-unit test system.

Figure 4-3
IEEE-488 connections



To avoid possible mechanical damage, stack no more than three connectors on any one unit.

NOTE *To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Available shielded cables from Keithley are models 7007-1 and 7007-2.*

To connect the Model 2000 multimeter to the IEEE-488 bus, follow these steps:

1. Line up the cable connector with the connector located on the rear panel. The connector is designed so that it will fit only one way. Figure 4-4 shows the location of the IEEE-488 connector.

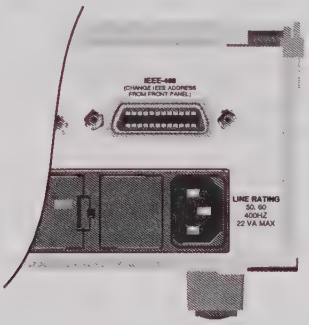


Figure 4-4
IEEE-488 connector location

2. Tighten the screws securely, making sure not to over tighten them.
3. Connect any additional connectors from other instruments as required for your application.
4. Make certain that the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See your controllers instruction manual for information about properly connecting to the IEEE-488 bus.

NOTE *You can only have 15 devices connected to a IEEE-488 bus, including the controller. The maximum cable length is either 20- meters or two meters times the number of devices, whichever is less. Not observing these limits may cause erratic bus operation.*

Selecting the primary address

The Model 2000 multimeter ships from the factory with a GPIB address of 16. When the multimeter powers up, it momentarily displays the primary address. You can set the address to a value of 0-30. Do not assign the same address to another device or to a controller that are on the same GPIB bus.

Usually controller addresses are 0 or 21, but see the controllers instruction manual for details. Make certain that the address of the controller is the same as that specified in the controllers programming language.

To change the primary address, follow these steps:

1. Access the GPIB configuration settings by pressing SHIFT then GPIB.

   You see: `GPIB:ON`, with `GPIB` blinking
2. Go to Address choice by pressing the ▼ key.

   You see: `ADDR:16`
3. Go to the numeric field by pressing the ► key.
4. Enter a new address from 0-30 by using the ▲ and ▼; press ENTER.
5. Return to the main display by pressing EXIT.

QuickBASIC 4.5 programming

Programming examples are written in Microsoft QuickBASIC 4.5 using the Keithley KPC-488.2 (or Capital Equipment Corporation) IEEE interface and the HP-style Universal Language Driver (CECHP).

Install the universal language driver

Before any programming example can be run, the Universal Language Driver must first be installed. To install the driver, from the DOS prompt, enter this command:

```
cechp
```

If you include the CECHP command in your AUTOEXEC.BAT file, the driver will automatically be installed every time you turn on your computer.

About program fragments

Program fragments are used to demonstrate proper programming syntax. As the name implies, only a fragment of the whole program is used to avoid redundancy.

At the beginning of each program, driver files have to be opened. The input terminator should be set for CRLF. For example:

```
OPEN "ieee" FOR OUTPUT AS #1
OPEN "ieee" FOR INPUT AS #2
PRINT #1, "interm crlf"
```

A typical program fragment includes an OUTPUT command and an ENTER command. The OUTPUT command sends a program message (command string) to the Model 2000 multimeter. If the program message includes a query command, then the ENTER command is required to get the response message from the Model 2000 multimeter. The ENTER command addresses the Model 2000 multimeter to talk. The following example program fragment demonstrates how OUTPUT and ENTER commands are used. Note that the commands assume address 16, which is the factory-set address of the Model 2000 multimeter.

```
PRINT #1, "output 16; :func 'volt:ac'; func?"
PRINT #1, "enter 16"
```

If you wish to display the response message on the CRT, the computer will have to read the message and then "print" it to the CRT display as follows:

```
LINE INPUT #2, A$
PRINT A$
```

The following programming example shows how all the above statements are used together. The program fragment is shown in bold typeface.

```
OPEN "ieee" FOR OUTPUT AS #1          'Open driver
OPEN "ieee" FOR INPUT AS #2           'Open driver
PRINT #1, "interm crlf"               'CRLF terminator
PRINT #1, "output 16;:func 'volt:ac'; func?"
                                      'Select ACV and query
PRINT #1, "enter 16"                  'Get response message
LINE INPUT #2, A$                     'Read response message
PRINT A$                              'Display message
```

General Bus Commands

General Bus Commands and Associated Statements

General commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 4-3 lists the general bus commands along with the programming statement for each command, which use the Keithley KPC-488.2 IEEE interface and the HP- style Universal Language Driver. Note that the commands requiring that the primary address be specified assume that the address is the factory-set address of 16.

Table 4-3
General bus commands and associated statements

Command	Programming statement	Effect on Model 2000 Multimeter
REN	REMOTE 16	Goes into effect when next addressed to listen.
IFC	ABORT	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT	LOCAL key locked out.
GTL	LOCAL 16	Cancel remote; restore front panel operation for the 2000.
	LOCAL	Cancel remote; restore front panel operation for all devices.
DCL	CLEAR	Return all devices to known conditions.
SDC	CLEAR 16	Returns Model 2000 to known conditions.
GET	TRIGGER 16	Initiates a trigger.
SPE, SPD	SPOLL 16	Serial Polls the Model 2000.

REN (remote enable)

The remote enable command is sent to the Model 2000 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true does not actually place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

Note that the instrument need not be in remote to be a talker.

Program fragment

```
PRINT #1, "remote 16"                    'Place the Model 2000 in remote;
                                          turn on REM annunciator
```

Note that all front panels controls except for LOCAL (and POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

IFC (interface clear)

The IFC command is sent by the controller to place the Model 2000 multimeter in the local, talker, listener idle states. The unit responds to the IFC command by canceling front panel TALK or LSTN lights, if the instrument was previously placed in one of those states.

Note that this command does not affect the status of the instrument; settings, data, and event registers are not changed.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100µs.

Program fragment

```
PRINT #1, "output 16; *idn?"          'Send query command
PRINT #1, "enter 16"                  'Read data; turn on TALK annunci-
                                       ator
SLEEP 3                               'Wait 3 seconds
PRINT #1, "abort"                     'Talker idle state; turn off TALK
                                       annunciator
```

LLO (local lockout)

Use the LLO command to prevent local operation of the instrument. After the unit receives LLO, all its front panel controls except the POWER are inoperative. In this state, pressing the LOCAL will not restore control to the front panel. The GTL command restores control to the front panel.

Program fragment

```
PRINT #1, "remote 16"                 'Place 2000 in remote
PRINT #1, "local lockout"             'Lock out front panel (including
                                       LOCAL key)
SLEEP 6                               'Wait 6 seconds
PRINT #1, "local 16"                  'Restore front panel operation
```

GTL (go to local)

Use the GTL command to put a remote-mode instrument into local mode. The GTL command also restores front panel key operation.

Program fragment

```
PRINT #1, "remote 16"                 'Place 2000 in remote
SLEEP 3                               'Wait 3 seconds
PRINT #1, "local 16"                  'Place 2000 in local mode
```

DCL (device clear)

Use the DCL command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When the Model 2000 multimeter receives a DCL command, it clears the Input Buffer and Output Queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. A DCL does not affect instrument settings and stored data.

Program fragment

```
PRINT #1, "clear"                    'Clear all devices
```

SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL.

Program fragment

```
PRINT #1, "clear 16"                 'Clear 2000
```

GET (group execute trigger)

GET is a GPIB trigger that is used as an arm, scan and/or measure event to control operation. The Model 2000 multimeter reacts to this trigger if it is the programmed control source. The control source is programmed from the SCPI: TRIGger subsystem.

With the instrument programmed and waiting for a GPIB trigger, the following program fragment will provide the GET:

Program fragment

```
PRINT #1, "trigger 16"                    'Trigger 2000 from over the bus
```

This sends IEEE-488 commands UNT UNL LISTEN 16 GET. When the command is executed, the trigger event occurs. (The command TRIGGER just sends GET. Any other listeners are triggered when the command is executed.)

SPE, SPD (serial polling)

Use the serial polling sequence to obtain the Model 2000 serial poll byte. The serial poll byte contains important information about internal functions, (see "status structure"). Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the Model 2000 multimeter.

Program fragment

```
PRINT #1, "spoll 16"                      'Serial poll the 2000
INPUT #2, S                               'Read serial poll byte
PRINT S                                   'Display the decimal value of the
                                           serial poll byte
```

Front panel GPIB operation

This section describes aspects of the front panel that are part of GPIB operation, including messages, status indicators, and the LOCAL key.

Error and status messages

See Section 2 for a list of error and status messages associated with IEEE-488 programming. The instrument can be programmed to generate an SRQ, and command queries can be performed to check for specific error conditions.

GPIB status indicators

The REM (remote), TALK (talk), LSTN (listen), and SRQ (service request) annunciators show the GPIB bus status. Each of these indicators is described below.

- REM — This indicator shows when the instrument is in the remote state. REM does not necessarily indicate the state of the REM line, as the instrument must be addressed to listen with REM true before the REM indicator turns on. When the instrument is in remote, all front panel keys, except for the LOCAL key, are locked out. When REM is turned off, the instrument is in the local state, and front panel operation is restored.
- TALK — This indicator is on when the instrument is in the talker active state. Place the unit in the talk state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. Place the unit in the talker idle state by sending an UNT (Untalk) command, addressing it to listen, or sending the IFC (Interface Clear) command.
- LSTN — This indicator is on when the Model 2000 Multimeter is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSTN is off when the unit is in the listener idle state. Place the unit in the listener idle state by sending UNL (Unlisten), addressing it to talk, or sending IFC (Interface Clear) command over the bus.
- SRQ — You can program the instrument to generate a service request (SRQ) when one or more errors or conditions occur. When this indicator is on, a service request has been generated. This indicator stays on until the serial poll byte is read or all the conditions that caused SRQ have ceased to exist. See "status structure" for more information.

LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument.

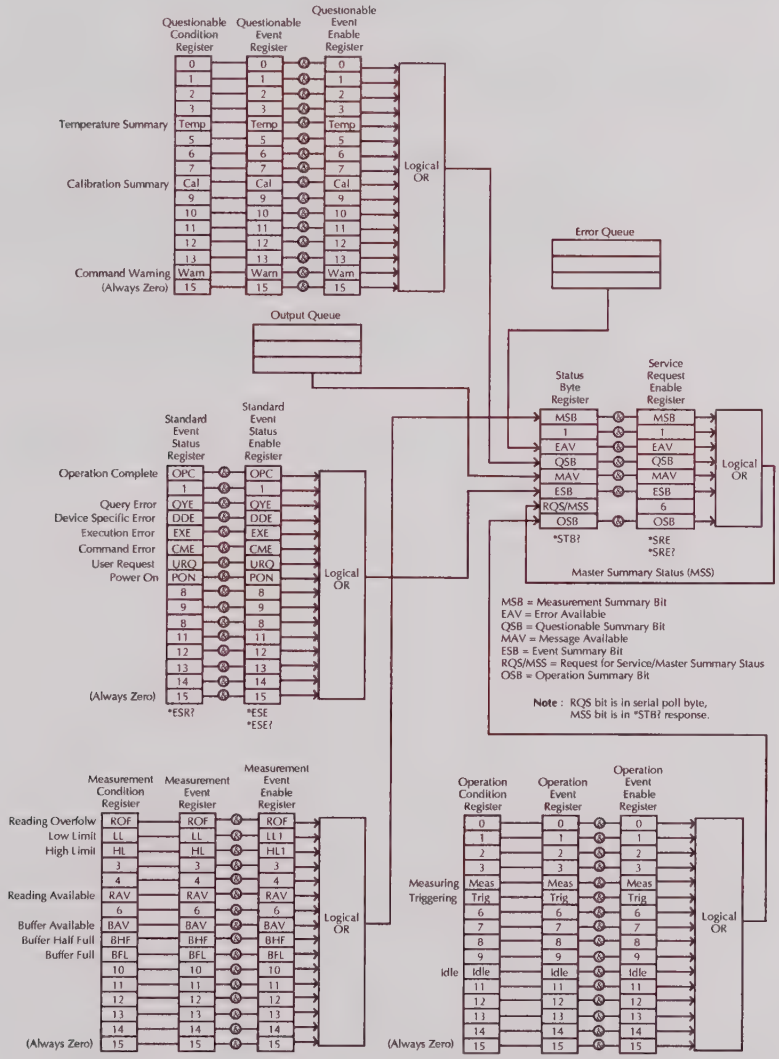
Pressing the LOCAL key also turns off the REM indicator and returns the display to normal if a user-defined message was displayed.

If the LLO (Local Lockout) command is in effect, the LOCAL key is also inoperative.

Status structure

See Figure 4-5 for the Model 2000 Multimeters status structure. Instrument events, such as errors, are monitored and manipulated by four status register sets. Notice that these status register sets feed directly into the Status Byte Register. More detailed illustrations of these register sets are provided by Figures 4-5 through 4-9.

Figure 4-5
Model 2000 status register structure



Condition registers

As Figure 4-5 shows, all status register sets have a condition register. A condition register is a real-time, read-only register that constantly updates to reflect the current operating conditions of the instrument. For example, while a measurement is being performed, bit B4 (Meas) of the Operation Condition Register is set. When the measurement is completed, bit B4 clears.

Use the :CONDition? query commands in the STATus Subsystem to read the condition registers. See Section 5 for more information.

Event registers

As Figure 4-5 shows, each status register set has an event register. An event register is a latched, read-only register whose bits are set by the corresponding condition register. Once a bit in an event register is set, it remains set (latched) until the register is cleared by a specific clearing operation. The bits of an event register are logically ANDed with the bits of the corresponding enable register and applied to an OR gate. The output of the OR gate is applied to the Status Byte Register.

Use the *ESR? Common Command to read the Standard Event Register. All other event registers are read using the :EVENt? query commands in the STATus Subsystem. See Section 5 for more information.

An event register is cleared when it is read. The following operations clear all event registers:

- Cycling power
- Sending *CLS

Enable registers

As Figure 4-5 shows, each status register set has an enable register. An enable register is programmed by you and serves as a mask for the corresponding event register. An event bit is masked when the corresponding bit in the enable register is cleared (0). When masked, a set bit in an event register cannot set a bit in the Status Byte Register (1 AND 0 = 0).

To use the Status Byte Register to detect events (i.e., serial poll), you must unmask the events by setting (1) the appropriate bits of the enable registers.

To program and query the Standard Event Status Register, use the *ESE and *ESE? Common Commands respectively. All other enable registers are programmed and queried using the :ENABle and :ENABLe? commands in the STATus Subsystem. See Section 5 for more information.

An enable register is not cleared when it is read. The following operations affect the enable registers:

- Cycling power - Clears all enable registers
- :STATus:PREset clears the following enable registers:
  Operation Event Enable Register
  Questionable Event Enable Register
  Measurement Event Enable Register
  *ESE 0 - Clears the Standard Event Status Enable Register.

Figure 4-6
Standard event status

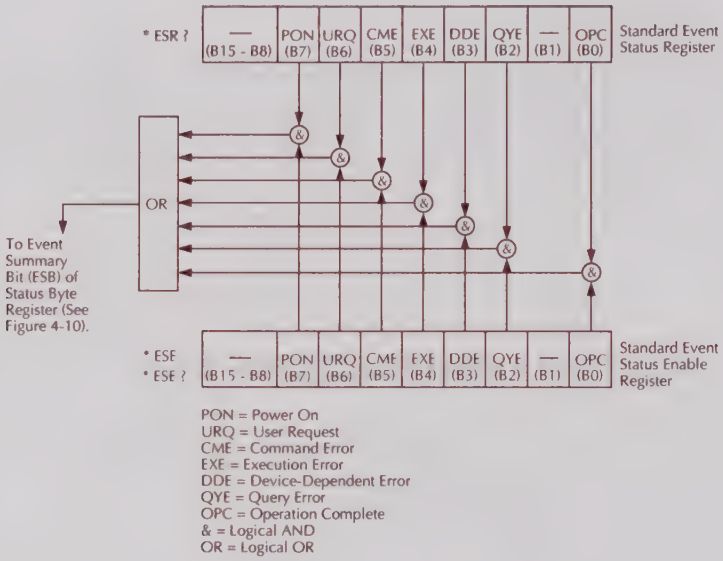


Figure 4-7
Operation event status

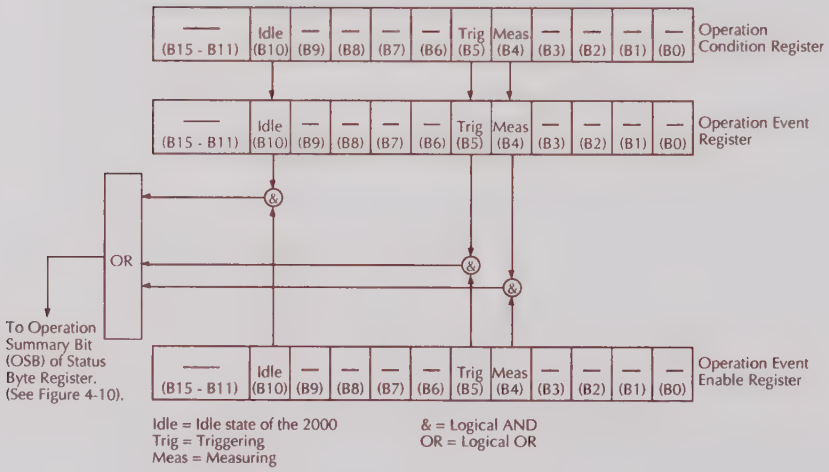


Figure 4-8
Measurement event status

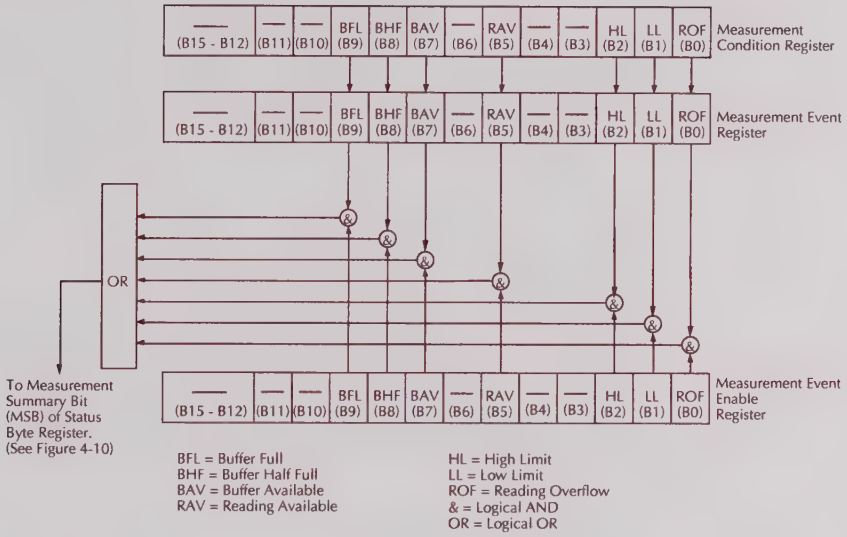
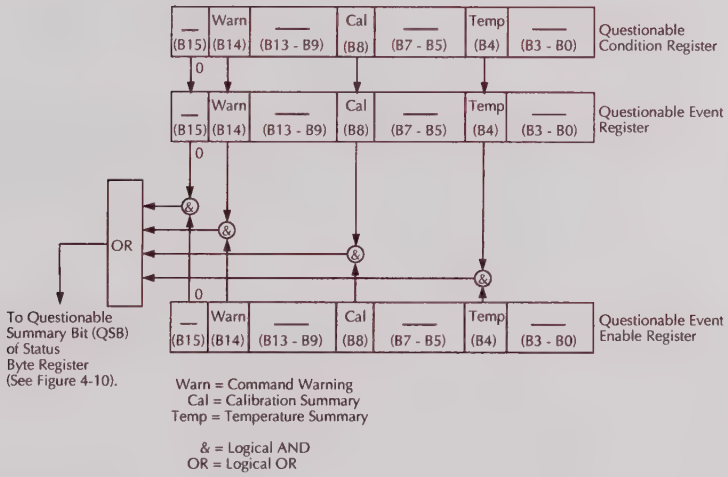


Figure 4-9
Questionable event status



Queues

The Model 2000 uses two queues, which are first-in, first-out (FIFO) registers:

- Output Queue - used to hold reading and response messages
- Error Queue - used to hold error and status messages

The Model 2000 Multimeter status model (Figure 4-5) shows how the two queues are structured with the other registers.

Output queue

The output queue holds data that pertains to the normal operation of the instrument. For example, when a query command is sent, the response message is placed on the Output Queue.

When data is placed in the Output Queue, the Message Available (MAV) bit in the Status Byte Register sets. A data message is cleared from the Output Queue when it is read. The Output Queue is considered cleared when it is empty. An empty Output Queue clears the MAV bit in the Status Byte Register.

Read a message from the Output Queue by addressing the Model 2000 multimeter to talk after the appropriate query is sent.

Error queue

The Error Queue holds error and status messages. When an error or status event occurs, a message that defines the error/status is placed in the Error Queue. This queue will hold up to 10 messages.

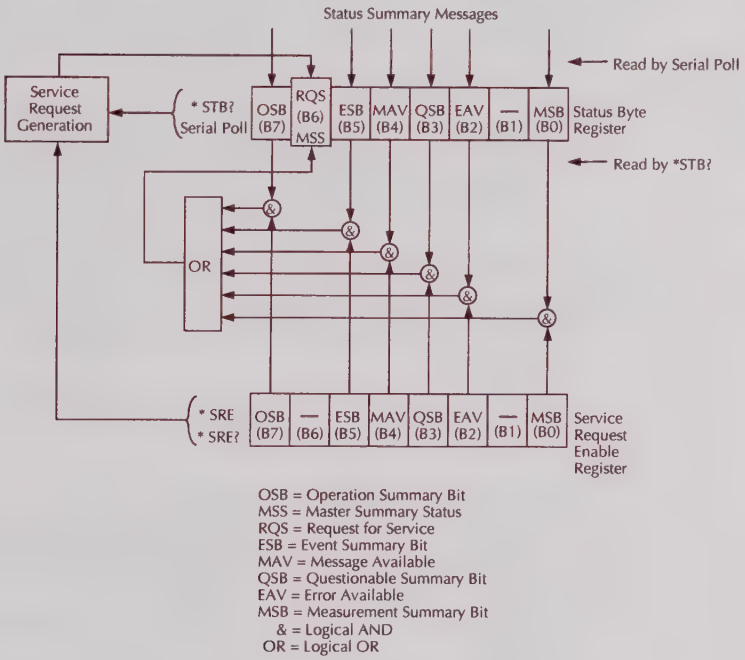
When a message is placed in the Error Queue, the Error Available (EAV) bit in the Status Byte Register is set. An error message is cleared from the Error/Status Queue when it is read. The Error Queue is considered cleared when it is empty. An empty Error Queue clears the EAV bit in the Status Byte Register. Read an error message from the Error Queue by sending either of the following SCPI query commands and then addressing the Model 2000 to talk:

- :SYSTem:ERRor?
- :STATus:QUEue

See Section 5 for complete information about reading error messages.

Status Byte and Service Request (SRQ)

Service request is controlled by two 8-bit registers: the Status Byte Register and the Service Request Enable Register. Figure 4-10 shows the structure of these registers.



OSB = Operation Summary Bit
MSS = Master Summary Status
RQS = Request for Service
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit
& = Logical AND
OR = Logical OR

Figure 4-10
Status byte and service request (SRQ)

Status Byte Register

The summary messages from the status registers and queues are used to set or clear the appropriate bits (B0, B2, B3, B4, B5, and B7) of the Status Byte Register. These bits do not latch, and their states (0 or 1) are solely dependent on the summary messages (0 or 1). For example, if the Standard Event Status Register is read, its register will clear. As a result, its summary message will reset to 0, which in turn will clear the ESB bit in the Status Byte Register.

Bit B6 in the Status Byte Register is either:

- The Master Summary Status (MSS) bit, sent in response to the *STB? command, indicates the status of any set bits with corresponding enable bits set.
- The Request for Service (RQS) bit, sent in response to a serial poll, indicates which device was requesting service by pulling on the SRQ line.

For a description of the other bits in the Status Byte Register, see "Common commands, *STB?"

The IEEE-488.2 standard uses the following common query command to read the Status Byte Register: *STB?.

When reading the Status Byte Register using the *STB? command, bit B6 is called the MSS bit. None of the bits in the Status Byte Register are cleared when using the *STB? command to read it.

The IEEE-488.1 standard has a serial poll sequence that also reads the Status Byte Register and is better suited to detect a service request (SRQ). When using the serial poll, bit B6 is called the RQS bit. Serial polling causes bit B6 (RQS) to reset. Serial polling is discussed in more detail later in this section entitled "Serial Poll and SRQ."

Any of the following operations clear all bits of the Status Byte Register:

- Cycling power.
- Sending the *CLS common command

Note: The MAV bit may or may not be cleared.

Service request enable register

This register is programmed by you and serves as a mask for the Status Summary Message bits (B0, B2, B3, B4, B5, and B7) of the Status Byte Register. When masked, a set summary bit in the Status Byte Register cannot set bit B6 (MSS/RQS) of the Status Byte Register. Conversely, when unmasked, a set summary bit in the Status Byte Register sets bit B6.

A Status Summary Message bit in the Status Byte Register is masked when the corresponding bit in the Service Request Enable Register is cleared (0). When the masked summary bit in the Status Byte Register sets, it is ANDed with the corresponding cleared bit in the Service Request Enable Register. The logic "1" output of the AND gate is applied to the input of the OR gate and, thus, sets the MSS/RQS bit in he Status Byte Register.

The individual bits of the Service Request Enable Register can be set or cleared by using the following common command: *SRE <NRf>

To read the Service Request Enable Register, use the *SRE? query command. The Service Request Enable Register clears when power is cycled or a parameter (n) value of zero is sent with the *SRE command *SRE 0).

Serial poll and SRQ

Any enabled event summary bit that goes from 0 to 1 will set RQS and generate a service request (SRQ). In your test program, you can periodically read the Status Byte Register to check if a service request (SRQ) has occurred and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request. Typically, service requests (SRQs) are managed by the serial poll sequence of the Model 2000. If an SRQ does not occur, bit B6 (RQS) of the Status Byte Register will remain cleared and the program will simply proceed normally after the serial poll is performed. If an SRQ does occur, bit B6 of the Status Byte Register will set and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

The serial poll automatically resets RQS of the Status Byte Register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

A serial poll clears RQS but does not clear MSS. The MSS bit stays set until all Status Byte event summary bits are cleared.

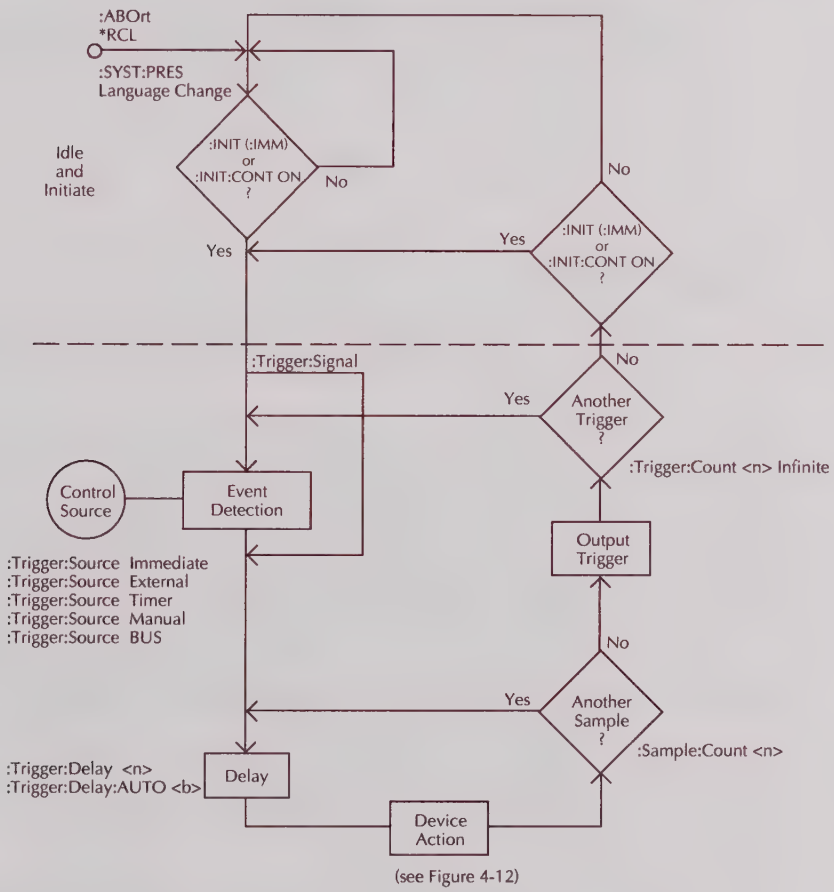
The following QuickBASIC 4.5 program (using the KPC-488.2 interface and the CECHP driver) demonstrates how serial poll can be used to detect an SRQ:

```
CLS
OPEN "ieee" FOR OUTPUT AS #1
OPEN "ieee" FOR INPUT AS #2
PRINT #1, "output 16; *cls"          'Clear Status Byte Register
PRINT #1, "output 16; *ese 32"       'Unmask command errors
PRINT #1, "output 16; *sre 32"       'Unmask event summary message
PRINT #1, "output 16; *ese"          'Error - missing parameter
SLEEP 1
PRINT #1, "SPOLL 02"                 'Serial poll 2000
INPUT #2, S                          'Read Status Byte Register
S=S OR 191                           'OR register with a mask
IF S= 255 THEN
GOSUB srq                            'Go to subroutine to acknowledge
                                      SRQ
END IF
PRINT
END
srq:
PRINT "SRQ Has Occurred--RQS (bit B6) is set (1)"
RETURN
```

Trigger model (GPIB operation)

This section describes how the Model 2000 Multimeter operates over the GPIB bus. The flowchart in Figure 4-11 summarizes operation over the bus and is called the trigger model. It is called the trigger model because operation is controlled by SCPI commands from the Trigger subsystem (see Section 5 for more information). Key SCPI commands are included in the trigger model.

Figure 4-11
Trigger model (remote operation)



Idle and initiate

The instrument is considered to be in the idle state whenever it is not operating. While in the idle state, the instrument cannot perform any measure or scan functions. You can send two commands over the bus to remove the instrument from the idle state:

- :INITiate
- :INITiate:CONTinuous ON

With continuous initiation enabled (:INITiate:CONTinuous ON), the instrument will not remain in the idle state after all programmed operations are completed. However, you can return the instrument to the idle state at any time by sending any of these commands:

- *RST
- ABORt
- *RCL
- SYST:PRES

Trigger model operation

Once the instrument is taken out of idle, operation proceeds through the trigger model down to the device action. In general, the device action includes a measurement and, when scanning, closes the next channel.

Control Source — As shown in Figure 4-11, a control source is used to hold up operation until the programmed event occurs. The control source options are explained as follows:

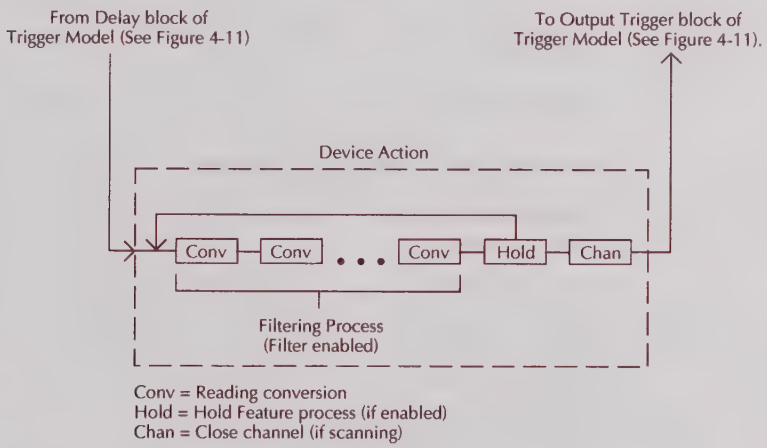
- IMMediate — Event detection is immediately satisfied allowing operation to continue.
- MANual — Event detection is satisfied by pressing the TRIG key. The Model 2000 Multimeter must be in LOCAL mode for it to respond to the TRIG key. Press the LOCAL key or send LOCAL 16 over the bus to remove the instrument from the remote mode.
- TIMer — Event detection is immediately satisfied on the initial pass through the loop Each subsequent detection is satisfied when the programmed timer interval (0 to 999999.999) seconds elapses. The timer source is only available during step/scan operation. The timer resets to its initial state when the instrument goes into the normal mode of operation or into the idle state.
- EXTernal — Event detection is satisfied when an input trigger via the TRIGGER LINK connector is received by the Model 2000 Multimeter.
- BUS — Event detection is satisfied when a bus trigger (GET or *TRG) is received by the Model 2000 Multimeter.

Delay — A programmable delay is available after the event detection. The delay can be manually set from 0 to 999999.999 seconds, or Auto Delay can be used. With Auto Delay enabled, the instrument automatically selects a delay based on the selected function and range. See the Auto Delay table in Section 3 for delay times.

Auto Delay is typically used for scanning. The nominal delay will be just long enough to allow each relay to settle before making the measurement.

Device Action — Figure 4-12 provides a detailed look at the device action. If the repeat filter is enabled, then the instrument samples the specified number of reading conversions to yield a single filtered reading. If the moving filter is active, or filter is disabled, then only one reading conversion is performed.

Figure 4-12
Device action (trigger model)



If the hold feature is enabled (see :HOLD commands in Section 5), then the first processed reading becomes the "seed" reading and operation loops back to the beginning of the device action. After the next reading is processed, it is compared to the programmed hold window (0.01% to 20%). If the reading is within the window, then operation again loops back to the beginning of the device action. This looping action continues until the specified number (2 to 100) of valid hold readings (readings within the window) have occurred. If one of the hold readings is not within the window, then the instrument acquires a new "seed" reading and repeats the hold process. After the hold is released, an audible beep is sounded to signal a valid measurement. The use of Hold is explained in Section 3.

If the instrument is performing a step or scan, then the next task for device action is to open the previous channel (if closed) and close the next channel.

If the filter, hold feature and scanning are disabled, the device action would simply be a single reading conversion.

Programming syntax

The information in this section covers syntax for both common commands and SCPI commands. For information not covered here, see the IEEE- 488.2 and SCPI standards.

Command words

Program messages are made up of one or more command words.

Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

*SAV <NRf>	Parameter (NRf) required
*RST	No parameter used
:INITiate:CONTinuous <b>	Parameter <b> required
:SYSTem:PRESet	No parameter used.

Put at least one space between the command word and the parameter.

- Brackets [ ]: Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

  :INITiate[:IMMediate]

  These brackets indicate that :IMMediate is implied (optional) and does not have to used. Thus, the above command can be sent in one of two ways:

  :INTiate or :INTiate:IMMediate

  Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

- Parameter types: The following are some of the more common parameter types:

  <b> Boolean: Used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation. Example:

  :CURRent:AC:RANGe:AUTO ON Enable auto ranging

  <name> Name parameter: Select a parameter name from a listed group. Example:

  <name> = NEVer
  = NEXt

  :TRACe:FEED:CONTrol NEXt

  <NRf> Numeric representation format: This parameter is a number that can be expressed as an integer (e.g., 8) a real number (e.g., 23.6) or an exponent (2.3E6). Example:

  :SYSTem:KEY 16 Press TEMP key from over the bus

  <n> Numeric value: A numeric value parameter can consist of an NRf number or one of the following name parameters: DEFault, MINimum, MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value. Examples:

:TRIGger:TIMer	0.1	Sets timer to 100 msec.
:TRIGger:TIMer	DEFault	Sets timer to 0.1 sec.
:TRIGger:TIMer	MINimum	Sets timer to 1 msec.
:TRIGger:TIMer	MAXimum	Sets timer to 999999.999 sec.

  <list> List: Specify one or more switching channels. Examples:

:ROUTe:SCAN (@1:10)	Specify scan list (1-10).
:ROUTe:SCAN (@2,4,6)	Specify scan list (2, 4, and 6).

- Angle Brackets < >: Angle brackets (< >) are used to denote a parameter type. Do not include the brackets in the program message. For example:

  :HOLD:STATe <b>

  The <b> indicates that a Boolean-type parameter is required. Thus, to enable the Hold feature, you must send the command with the ON or 1 parameter as follows.

  :HOLD:STATe ON or 1

Query commands

This type of command requests (queries) the currently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form, Example:

:TRIGger:TIMer? Queries the timer interval.

Most command that require a numeric parameter(<n>) can also use the DEFault, MINimum, and MAXimum parameters for the query form. These query forms are used to determine the *RST default value and the upper and lower limits for the fundamental command. Examples:

:TRIGger:TIMer?	DEFault	Queries the *RST default value.
:TRIGger:TIMer?	MINimum	Queries the lowest allowable value.
:TRIGger:TIMer?	MAXimum	Queries the largest allowable value.

Case sensitivity

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination. Examples:

*RST	=	*rst
:DATA?	=	:data?
:SYSTem:PRESet	=	:system:preset

Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. The command subsystem tables in Section 5 provide the in the long-form version. However, the short-form version is indicated by upper case characters. Examples:

:SYSTem:PRESet	long-form
:SYST:PRES	short form
:SYSTem:PRES	long-form and short-form combination

Note that each command word must be in long-form or short-form, and not something in between. For example, :SYSTe:PRESe is illegal and will generate an error. The command will not be executed.

Short-form rules

Use the following rules to determine the short-form version of any SCPI command:

- If the length of the command word is four letters or less, no short form version exists. Example:

  :auto = :auto

- These rules apply to command words that exceed four letters:
- If the fourth letter of the command word is a vowel, delete it and all the letters after it. Example

  :immediate = :imm

- Rule exception-The short form version of the following command uses only the first two letters of the word:

  :TCouple = :tc

- If the fourth letter of the command word is a consonant, retain it but drop all the letters after it. Example:

  :format = :form

- If the command contains a question mark (?; query) or a non- optional number included in the command word, you must include it in the short-form version. Example:

  :delay? = :del?

- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message.

Program messages

A program message is made up of one or more command words sent by the computer to the instrument. Each common command is simply a three letter acronym preceded by an asterisk (*). SCPI commands are categorized in the :STATus subsystem and are used to help explain how command words are structured to formulate program messages.

:STATus	Path (Root)
:OPERation	Path
:ENABle <NRf>	Command and parameter
:ENABle?	Query command
:PRESet	Command

Single command messages

The above command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:OPERation) and a command (:PRESet). The third path is made up of one command for the :OPERation path. The three commands in this structure can be executed by sending three separate program messages as follows:

```
:stat:oper:enab <NRf>
:stat:oper:enab?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

Multiple command messages

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). Here is an example showing two commands in one program message:

```
:stat:oper; :stat:oper:enab <NRf>
```

When the above is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. Example:

```
:stat:oper:enab <NRf>; enab?
```

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be typed in without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

Command path rules

- Each new program message must begin with the root command, unless it is optional (e.g., [:SENSe]). If the root is optional, simply treat a command word on the next level as the root.
- The colon (:) at the beginning of a program message is optional and need not be used. Example:

  :stat:pres = stat:pres

- When the path pointer detects a colon (:) it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message (see next rule).
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets back to the root level.
- The path pointer can only move down. It cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

Using common commands and SCPI commands in the same message

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer. Example:

:stat:oper:enab <NRf>; *ESE <NRf>

Program message terminator (PMT)

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a multiple command program message must be terminated:

:rout:open:all; scan (@1:5) <PMT>

Command execution rules

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and, of course, is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.

Response messages

A response message is the message sent by the instrument to the computer in response to a query command program message.

Sending a response message

After sending a query command, the response message is placed in the Output Queue. When the Model 2000 Multimeter is then addressed to talk, the response message is sent from the Output Queue to the computer.

Multiple response messages

If you send more than one query command in the same program message (see the paragraph entitled, "Multiple Command Messages"), the multiple response messages for all the queries is sent to the computer when the Model 2000 is addressed to talk. The responses are sent in the order that the query commands were sent and are separated by semicolons (;). Items within the same query are separated by commas (,). The following example shows the response message for a program message that contains four single item query commands:

0; 1; 1; 0

Response message terminator (RMT)

Each response is terminated with an LF (line feed) and EOI (end or identify). The following example shows how a multiple response message is terminated:

0; 1; 1; 0; <RMT>

Message exchange protocol

Two rules summarize the message exchange protocol:

Rule 1. You must always tell the Model 2000 what to send to the computer.

The following two steps must always be performed to send information from the instrument other computer:

1. Send the appropriate query command(s) in a program message.
2. Address the Model 2000 to talk.

Rule 2. The complete response message must be received by the computer before another program message can be sent to the Model 2000.

Common Commands

Common commands (summarized in Table 4-4) are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Table 4-4
IEEE-488.2 common commands and queries

Mnemonic	Name	Description
*CLS	Clear status	Clears all event registers and Error Queue.
*ESE <NRf>	Event enable command	Program the Standard Event Enable Register.
*ESE?	Event enable query	Read the Standard Event Enable Register.
*ESR?	Event status register query	Read the Standard Event Enable Register and clear it.
*IDN?	Identification query	Returns the manufacturer, model number, serial number and firmware revision levels of the unit.
*OPC	Operation complete command	Set the Operation Complete bit in the Standard Event Status Register after all pending commands have been executed.
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.
*OPT?	Option identification query	Returns an ID code that indicates which memory option is installed and whether or not the optional scanner card is installed.
*RCL <NRf>	Recall command	Returns the Model 2000 to the setup configuration stored in the specified memory location.
*RST	Reset command	Returned the Model 2000 to the *RST default conditions.
*SAV <NRf>	Save command	Saves the current setup to the specified memory location.
*SRE <NRf>	Service request enable command	Programs the Service Request Enable Register.
*SRE?	Service request enable query	Reads the Service Request Enable Register.
*STB	Read status byte query	Reads the Status Byte Register.
*TRG	Trigger command	Sends a bus trigger to the 2000.
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.
*WAI	Wait-to-continue command	Wait until all previous commands are executed.

*CLS — Clear Status

Clear status registers and error queue

Description

Use the *CLS command to clear (reset to 0) the bits of the following registers in the Model 2000:

- Standard Event Register
- Operation Even Register
- Error Queue
- Measurement Event Register
- Questionable Event Register

This command also forces the instrument into the operation complete command idle state and operation complete query idle state.

*ESE <NRf> — Event Enable

Program the standard event enable register

*ESE? — Event Enable Query

Read the standard event register

Parameters

<NRf> =	0	Clear register
	1	Set OPC (B0)
	4	Set QYE (B2)
	8	Set DDE (B3)
	16	Set EXE (B4)
	32	Set CME (B5)
	64	Set URQ (B6)
	128	Set PON (B7)
	255	Set all bits

Description

Use the *ESE command to program the Standard Event Enable Register. This command is sent with the decimal equivalent of the binary value that determines the desired state (0 or 1) of the bits in the register. This register is cleared on power-up.

This register is used as a mask for the Standard Event Register. When a standard event is masked, the occurrence of that event will not set the Event Summary Bit (ESB) in the Status Byte Register. Conversely, when a standard event is unmasked (enabled), the occurrence of that event sets the ESB bit. For information on the Standard Event Register and descriptions of the standard event bits see the next section.

A cleared bit (0) in the enabled register prevents (masks) the ESB bit in the Status Byte Register from setting when the corresponding standard event occurs. A set bit (1) in the enable register allows (enables) the ESB bit to set when the corresponding standard event occurs.

The Standard Event Enable Register is shown in Figure 4-13 and includes the decimal weight of each bit. The sum of the decimal weights of the bits that you wish to be set is the parameter value that is sent with the *ESE command. For example, to set the CME and QYE bits of the Standard Event Enable Register, send the following command:

*ESE 36

Where: CME (bit B5) = Decimal 32
QYE (bit B2) = Decimal 4
<NRf> = 36

If a command error (CME) occurs, bit B5 of the Standard Event Status Register sets. If a query error (QYE) occurs, bit B2 of the Standard Event Status Register sets. Since both of these events are unmasked (enabled) the occurrence of any one of them causes the ESB bit in the Status Byte Register to set.

Read the Standard Event Status Register using the *ESE? query command.

Figure 4-13
Standard event enable register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	PON	URQ	CME	EXE	DDE	QYE	—	OPC
Decimal Weighting	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	0/1	0/1	0/1	0/1	0/1	—	0/1

Note : Bits B8 through B15 are not shown since they are not used.

Value : 1 = Enable Standard Event
0 = Disable (Mask) Standard Event

Events : PON = Power On
URQ = User Request
CME = Command Error
EXE = Execution Error
DDE = Device-dependent Error
QYE = Query Error
OPC = Operation Complete

*ESR? — Event Status Register Query

Read the standard event status register and clear it

Description

Use this command to acquire the value (in decimal) of the Standard Event Register (see Figure 4-14). The binary equivalent of the returned decimal value determines which bits in the register are set. The register is cleared on power-up or when *CLS is sent.

A set bit in this register indicates that a particular event has occurred. For example, for an acquired decimal value of 48, the binary equivalent is 00110000. From this binary value, bits B4 and B5 of the Standard Event Status Register are set. These bits indicate that a device-dependent error and command error have occurred.

The bits of the Standard Event Status Register are described as follows:

- Bit B0, Operation Complete — A set bit indicates that all pending selected device operations are completed and the Model 2000 is ready to accept new commands. This bit only sets in response to the *OPC? query command.
- Bit B1 — Not used
- Bit B2, Query Error (QYE) — A set bit indicates that you attempted to read data from an empty Output Queue.
- Bit B3, Device-dependent Error (DDE) — A set bit indicates that an instrument operation did not execute properly due to some internal condition.
- Bit B4, Execution Error (EXE) — A set bit indicates that the Model 2000 detected an error while trying to execute a command.
- Bit B5, Command Error (CME) — A set bit indicates that a command error has occurred. Command errors include:
- IEEE-488.2 syntax error: Model 2000 received a message that does not follow the defined syntax of the IEEE-488.2 standard.
- Semantic error: Model 2000 received a command that was misspelled, or received an optional IEEE-488.2 command that is not implemented.
- The instrument received a Group Execute Trigger (GET) inside a program message.
- Bit B6, User Request (URQ) — A set bit indicates that the LOCAL key on the Model 2000 front panel was pressed.
- Bit B7, Power ON (PON) — A set bit indicates that the Model 2000 has been turned off and turned back on since the last time this register has been read.

Figure 4-14
Standard event status regster

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	PON	URQ	CME	EXE	DDE	QYE	—	OPC
Decimal Weighting	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	0/1	0/1	0/1	0/1	0/1	—	0/1

Note : Bits B8 through B15 are not shown since they are not used.

Value : 1 = Event Bit Set
0 = Event Bit Cleared

Events : PON = Power On
URQ = User Request
CME = Command Error
EXE = Execution Error
DDE = Device-dependent Error
QYE = Query Error
OPC = Operation Complete

*IDN? — Identification Query **Read the identification code**

Description

The identification code includes the manufacturer, model number, serial number, and firmware revision levels, and is sent in the following format:

KEITHLEY INSTRUMENTS INC., MODEL 2000, xxxxxxx, yyyyy/zzzzz

Where: xxxxxxx is the serial number
yyyyy/zzzzz is the firmware revision levels of the digital board ROM and display board ROM.

*OPC — Operation Complete

Set the OPC bit in the standard event status register after all pending commands are complete

Description

On power-up or when the *CLS or *RST is executed, the Model 2000 goes into the Operation Complete Command Idle State (OCIS). In this state, no pending overlapped commands exist. The Model 2000 has three overlapped commands:

- :INITiate
- :INITiate:CONTinuous ON
- *TRG

When you send the *OPC command, the Model 2000 exits from OCIS and enters the Operation Complete Command Active State (OCAS). In OCAS, the instrument continuously monitors the No-Operation-Pending flag. After the last pending overlapped command is completed (No-Operation- Pending flag set to true), the Operation Complete (OPC) bit in the Standard Event Status Register sets, and the instrument goes back into OCIS.

Note that the instrument always goes into OCAS when *OPC is executed. If no pending command operations are present (e.g. trigger model in idle state), the Model 2000 immediately sets the OPC bit and returns to OCIS.

When used with the :INITiate or :INITiate:CONTinuous ON command, the OPC bit of the Standard Event Status Register will not set until the Model 2000 goes back into the idle state. The initiate operations are not considered finished until the instrument goes into idle.

When used with the *TRG command, the OPC bit will not set until the operations associated with the *TRG command (and the initiate command) are finished. The *TRG command is considered to be finished when the Device Action completes or when operation stops a control source to wait for an event (see Trigger Model in this section).

To use the *OPC exclusively with the *TRG command, first force the completion of the initiate command so that only the *TRG command is pending. Do this by sending the :ABORt command to place the instrument in idle, which (by definition) completes the initiate command. Since continuous initiation is on, operation continues on into the Trigger Model. After sending the *TRG command, the OPC bit sets when the *TRG command is finished.

Program Fragment

```
GOSUB Read Register                    'Clear register by reading it
PRINT #1, "output 16; :init            'Place 2000 in idle
:cont off; :abort"
PRINT #1, "output 16; :init;*opc"      'Start measurements and send *OPC
SLEEP 2                                'Wait two seconds
GOSUB ReadRegister                     'Read register to show that OPC is
                                        not set
PRINT #1, "output 16; :abort"          'Place 2000 back in idle
GOSUB ReadRegister                     'Read register to show that OPC is
                                        now set

END
ReadRegister:
PRINT #1, "output 16; *esr?"           'Query Standard Event Status Reg-
                                        ister
PRINT #1, "enter 16"                   'Get response message from 2000
LINE INPUT #2, a$                      'Read decimal value of register
PRINT a$
RETURN
```

*OPC? — Operation Complete Query

Place a "1" in the output queue after all pending operations are completed

Description

On power-up or when the *CLS or *RST is executed, the Model 2000 goes into the Operation Complete Command Query Idle State (OQIS). In this state, no pending overlapped commands exist. The Model 2000 has three overlapped commands:

- :INITiate
- :INITiate:CONTinuous ON
- *TRG

When you send the *OPC? command, the Model 2000 exits from OQIS and enters the Operation Complete Command Query Active State (OQAS). In OQAS, the instrument continuously monitors the No-Operation-Pending flag. After the last pending overlapped command is completed (No- Operation-Pending flag set to true), an ASCII character "1" is placed into the Output Queue, the Message Available (MAV) bit in the Status Byte sets, and the instrument goes back into OQIS. Addressing the Model 2000 to talk sends the ASCII "1" to the computer.

Note that the instrument always goes into OQAS when *OPC? is executed. If no pending command operations are present (e.g. trigger model in idle state), the Model 2000 immediately places an ASCII "1" in the Output Queue, sets the MAV bit and returns to OQIS.

When used with the :INITiate or :INITiate:CONTinuous ON command, an ASCII "1" will not be sent to the Output Queue and the MAV bit will not set until the Model 2000 goes back into the idle state. The initiate operations are not considered finished until the instrument goes into the idle state.

When used with the *TRG command, an ASCII "1" will not be placed into the Output Queue and the MAV bit will not set until the operations associated with the *TRG command (and the initiate command) are finished. The *TRG command is considered to be finished when the Device Action completes or when operation stops at a control source to wait for an event (see the Trigger Model in this section).

To use *OPC? exclusively with the *TRG command, first force the completion of the initiate command so that only the *TRG command is pending. To do this, send the :ABORt command to place the instrument in idle, which (by definition) completes the initiate command. Since continuous initiation is on, operation continues on into the Trigger Model. After sending the *TRG command, an ASCII "1" is placed in the Output Queue and the MAV bit sets when the *TRG command is finished.

After *OPC? is executed, additional commands cannot be sent to the Model 2000 until the pending overlapped commands are finished. For example, :INITiate:CONTinuous ON followed by *OPC? locks up the instrument and requires a device clear (DCL or SDC) before it will accept any more commands.

Note: See *OPC, *TRG and *WAI for more information.

Program Fragment

```
PRINT #1, "output 16; :syst:pres"      'Select defaults
PRINT #1, "output 16; :init:cont off;:abort"
                                       'Place 2000 in idle
PRINT #1, "output 16; :trig:coun 1; sour tim"
PRINT #1, "output 16; :samp:coun 5"    'Program for 5 measurements and
                                        stop (idle)
PRINT #1, "output 16; :init; *opc?"    'Start measurements and send
                                        *opc?
PRINT #1, "enter 16"                   'Get response when 2000 goes into
                                        idle
LINE INPUT #2, a$                      'Read contents of Output Queue
PRINT a$                               'Display the ASCII "1"
```

*OPT? — Option Identification Query

Determine if an option is installed

Description

The response message indicates the presence or absence of an optional scanner card. For example:

0	No scanner card installed
200X-SCAN	Scanner card installed

*RCL — Recall

Return to setup stored in memory

Parameters

<NRf>=0

Description

Use this command to return the Model 2000 to the configuration stored in memory. The *SAV command is used to store the setup configuration in memory location.

Only one setup configuration can be saved and recalled.

The Model 2000 ships from the factory with :SYSTen:PRESet defaults loaded into the available setup memory. If a recall error occurs, the setup memory defaults to the :SYSTem:PRESet values.

*RST — RESET

Return 2000 to *RST defaults

Description

When the *RST command is sent, the Model 2000 performs the following operations:

1. Returns the Model 2000 to the *RST default conditions (see SCPI tables).
2. Cancels all pending commands.
3. Cancels response to any previously received *OPC and *OPC? commands.

*SAV — Save

Save present setup in memory

Parameters

<NRf>=0

Description

Use the *SAVE command to save the current instrument setup configuration in memory for later recall. Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to the saved setup configuration.

Only one setup configuration can be saved and recalled.

*SRE <NRf> — Service Request Enable

Program service request enable register

*SRE? — Service Request Enable Query

Read service request enable register

Parameters

<NRf>=	0	Clears enable register
	1	Set MSB bit (Bit 0)
	4	Set EAV bit (Bit 2)
	8	Set QSB bit (Bit 3)
	16	Set MAV bit (Bit 4)
	32	Set ESB (Bit 5)
	128	Set OSB (Bit 7)
	255	Set all bits

Description

Use the *SRE command to program the Service Request Enable Register. Send this command with the decimal equivalent of the binary value that determines the desired state (0 or 1) of each bit in the register. This register is cleared on power-up.

This enable register is used along with the Status Byte Register to generate service requests (SRQ). With a bit in the Service Request Enable Register set, an SRQ occurs when the corre-

sponding bit in the Status Byte Register is set by an appropriate event. For more information on register structure, see the information presented earlier in this section.

The Service Request Enable Register is shown in Figure 4-15. Notice that the decimal weight of each bit is included in the illustration. The sum of the decimal weights of the bits that you wish to set is the value that is sent with the *SRE command. For example, to set the ESB and MAV bits of the Service Request Enable Register, send the following command:

*SRE 48

Where: ESB (bit B5) = Decimal 32
MAV(bit B4) = Decimal 16
<NRf> = 48

The contents of the Service Request Enable Register can be read using the *SRE? query command.

Figure 4-15
Service request enable register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	OSB	—	ESB	MAV	QSB	EAV	—	MSB
Decimal Weighting	128 (2^7)	—	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	—	0/1	0/1	0/1	0/1	—	0/1

Value : 1 = Enable Service Request Event
0 = Disable (Mask) Service Request Event

Events : OSB = Operation Summary Bit
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit

*STB? — Status Byte Query

Read status byte register

Description

Use the *STB? query command to acquire the value (in decimal) of the Status Byte Register. The Status Byte Register is shown in Figure 4-16. The binary equivalent of the decimal value determines which bits in the register are set.

All bits, except Bit B6, in this register are set by other event registers and queues. Bit 6 sets when one or more enabled conditions occur.

The *STB? query command does not clear the status byte register. This register can only be cleared by clearing the related registers and queues. See "status structure" for details.

For example, for an acquired decimal value of 48, the binary equivalent is 00110000. This binary value indicates that bits 4 and 5 if the Status Byte Register are set.

The bits of the Status Byte Register are described as follows:

- Bit 0, Measurement Status (MSB)-A set bit indicates that a measurement event has occurred. The event can be identified by reading the Measurement Event Status Register using the :STATus:MEASurement? command (see Section 5 for details).
- Bit 1-Not used.
- Bit 2, Error Available (EAV)-A set bit indicates that an error or status message is present in the Error Queue. The message can be read using one of the following SCPI commands:

  :SYSTem:ERRor?
  :STATus:QUEue?

  See Section 5 for more information.

- Bit 3, Questionable Summary Bit (QSB)-A set bit indicates that a calibration error has occurred.
- Bit 4, Message Available (MAV)-A set bit indicates that a message is present in the Output Queue. The message is sent to the computer when the Model 2000 is addressed to talk.
- Bit 5, Event Summary Bit (ESB)-A set bit indicates that an enabled standard event has occurred. The event can be identified by reading the Standard Event Status Register using the *ESE? query command.
- Bit 6, Master Summary Status (MSS)/Request Service (RQS)-A set bit indicates that one or more enabled Status Byte conditions have occurred. Read the MSS bit by using the STB? query command, or perform a serial poll to detect the occurrence of a service request (RQS bit set).
- Bit 7, Operation Summary (OSB)-A set bit indicates that an enabled operation event has occurred. The event can be identified by reading the Operation Event Status Register using the :STATus:OPERation? query command (see Section 5 for details).

Figure 4-16
Status byte register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	OSB	MSS, RQS	ESB	MAV	QSB	EAV	—	MSB
Decimal Weighting	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	0/1	0/1	0/1	0/1	0/1	—	0/1

Value : 1 = Event Bit Set
0 = Event Bit Cleared

Events : OSB = Operation Summary Bit
MSS = Master Summary Status
RQS = Request Service
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit

*TRG — Trigger Send bus trigger to 2000

Description

Use the *TRG command to issue a GPIB trigger to the Model 2000. It has the same effect as a group execute trigger (GET).

Use the *TRG command as an event to control operation. The Model 2000 reacts to this trigger if BUS is the programmed control source. The control source is programmed from the TRIGger subsystem (see Section 5).

*TST?-Self-Test Query Run self test and read result

Description

Use this query command to perform a checksum test on ROM. The command places the coded result (0 or 1) in the Output Queue. When the Model 2000 is addressed to talk, the coded result is sent from the Output Queue to the computer.

A returned value of zero (0) indicates that the test passed, and a value of one (1) indicates that the test has failed.

*WAI — Wait-to-Continue Prevent execution of commands until previous commands are completed

Description

Two types of device commands exist:

- Sequential commands-A command whose operations are allowed to finish before the next command is executed.
- Overlapped commands-A command that allows the execution of subsequent commands while device operations of the Overlapped command are still in progress.

Use the *WAI command to suspend the execution of subsequent commands until the device operations of all previous Overlapped commands are finished. The *WAI command is not needed for Sequential commands.

The Model 2000 has three overlapped commands:

- :INITiate
- :INITiate:CONTinuous ON
- *TRG

Note: See *OPC, *OPC? and *TRG for more information.

The :INITiate commands remove the Model 2000 from the idle state. The device operations of :INITiate are not considered complete until the Model 2000 returns to idle. By sending the *WAI command after the :INITiate command, all subsequent commands will not execute until the Model 2000 goes back into idle.

The *TRG command issues a bus trigger that could be used to provide the arm, scan, and measure events for the Trigger Model. By sending the *WAI command after the *TRG command, subsequent commands will not executed until the pointer for the Trigger Model has finished moving in response to *TRG and has settled at its next state.

Program Fragment

```
PRINT #1, "output 02; :syst:pres"      'Select defaults
PRINT #1, "output 02; :init:cont off;:abort"
                                       'Place 2000 in idle
PRINT #1, "output 02; :trig:coun 1;sour tim"
                                       'Program for 30 measurements and
                                       'then stop (idle)
PRINT #1, "output 02; :samp:coun 30"
PRINT #1, "output 02;:init; *wai"      'Start measurements and send *wai
PRINT #1, "output 02; :data?"          'Query a reading
PRINT #1, "enter 02"                   'Get reading after 2000 goes into
                                        idle
LINE INPUT #2, a$                      'Read the reading
PRINT a$                               'Display the reading
```

KEITHLEY

Model 2000

Multimeter

Quick Reference Guide

Model 2000 Multimeter

Quick Reference Guide

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Table of Contents

Safety Precautions 1

Introduction 5

Front Panel Operation Summary 6

Remote Operation Summary 22

Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or

test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the

combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

10-99

Introduction

This quick reference guide includes summary information on front panel and remote operation for the Model 2000 Multimeter. For detailed operating information, consult the Model 2000 User's Manual.

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Front Panel Operation Summary

Power-on defaults

Power-on defaults are those settings the instrument assumes when it is turned on. The Model 2000 offers two choices for the settings: user or factory. With user, the instrument will power-on to the last configuration that you saved. With factory, the instrument will power on to the factory default settings.

To store a user configuration in memory:

1. Configure the instrument as desired for USER default.
2. Press SHIFT and then SAVE.
3. Use the ▲ and ▼ keys to select YES or NO. Note: Select NO if you do not wish to change the last configuration that you saved.
4. Press ENTER.

To restore factory or user settings:

1. Press SHIFT and then SETUP.
2. Use the ▲ and ▼ keys to select FACTory or USER.
3. Press ENTER.

NOTE: Factory default settings are listed in Table 2.

Instrument connections

Basic connections for Model 2000 measurements are shown in Figure 1. These drawings show connections to the front panel terminals (INPUTS switch in the FRONT position). If using the rear panel terminals, place the

INPUTS switch in the REAR position. Note that current (DCI and ACI) measurements cannot be made from the rear panel terminals.

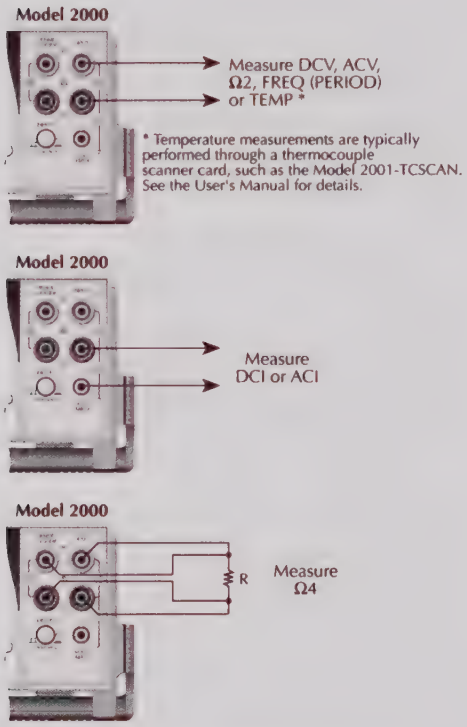

Figure 1. Basic measurement connections

For resistance measurements (Ω2 and Ω4) greater than 100kΩ, more stable readings can be achieved by using shielding. Place the resistance in a shielded enclosure and connect the shield to INPUT LO. Shielded cable should be used such that the shield (INPUT LO) encircles the other cable conductor(s).

Maximum inputs for the Model 2000 are summarized in Table 1.

Table 1. Maximum inputs

Function	Maximum input
DCV	1000V peak
ACV	750V rms, 1000V peak, 8×10^7V•Hz
DCI	3A dc, 250V
ACI	3A rms, 250V
FREQ (PERIOD)	1000V peak, 8×10^7V•Hz

Basic measurement procedure

1. Connect the instrument as explained in "Instrument connection".
2. From the function keys, select the desired measurement function.
3. Use the RANGE keys to select autoranging or a manual range. Pressing the AUTO range key toggles autoranging. You can select a different range with the ▲ and ▼ RANGE keys.
4. Take a reading from the display.

Storing readings (2 to 1024)

1. Set up the instrument for the desired configuration.
2. Press the STORE key.
3. Use the ◀, ▶, ▲ and ▼ keys to select the number of readings to store in the buffer.
4. Press ENTER to start the storage process. The asterisk (*) annunciator turns on to indicate a data storage operation. It turns off when the storage is finished.

Recalling readings

1. Press the RECALL key. The BUFFER annunciator indicates that stored readings are being displayed. The arrow annunciator indicates that more data can be viewed with the ◀, ▶, ▲ and ▼ keys.
2. Use the ◀, ▶, ▲ and ▼ keys to navigate through the reading numbers, reading values, and statistics. For any of the buffer statistics (maximum, minimum, average, standard deviation) the STAT annunciator is on.
3. Use the EXIT key to return to the normal display.

Changing speed, resolution and filter

RATE — Measurement speed (reading RATE) can be changed for any measurement function except frequency, period, continuity and diode test. Use the RATE key to select FAST, MEDium or SLOW. Use FAST (0.1 PLC) if speed is of primary importance (at the expense of increased noise and fewer usable digits of resolution). SLOW (10 PLC) provides better noise performance at the expense of speed. MEDium (1 PLC) provides a compromise between noise and speed.

DIGITS — Display resolution can be changed for any measurement function. Use the DIGITS key to select the desired number of digits (3½ to 6½).

FILTER — Filter state (on/off) and configuration can be changed for any measurement function, except frequency, period, continuity and diode test. The FILTER key toggles between filter on (FILT annunciator on) and filter off. After pressing FILTER to enable the filter, you can then enter the filter count (1 to 100), and select the filter type (moving or repeating). (If the FILT annunciator is already on, press FILTER twice before entering the filter count.)

Changing temperature measurement configuration

Press SHIFT and then TCOUPL. Three choices are available using the ▲ and ▼ keys:

- UNITS — C, K or F. Specify units.
- TYPE — J, K or T. Specify thermocouple type.
- JUNC — SIM or CH1. Simulate a reference junction temperature (for direct thermocouple connection to the INPUT), or use the reference junction (channel 1) provided on a switching card. In order to keep the reference calculations updated and accurate, Channel 1 needs to be read periodically.

To assign a value to a parameter, use the ▲ and ▼ keys to scroll to the desired parameter. Select the ▶ key, and use the ▲ and ▼ keys to scroll through and choose the preferred value. Select the ENTER key to save any changes.

Relative (rel)

Rel can be used to null offsets or subtract a baseline reading from present and future readings. When rel is enabled by pressing REL (REL annunciator on), the instrument uses the present reading as the relative value. Subsequent readings will be the difference between the actual input value and the rel value. You can define a rel value for each function. Pressing REL a second time disables rel.

Math

To enable and configure a math operation, press SHIFT and then the desired math key (MX+B, %, dBm or dB). Use the ◀, ▶, ▲ and ▼ keys to configure the math operation and press ENTER when done. Pressing SHIFT and then the related math key a second time disables the math operation.

MX+B

$$Y = mX + b$$

Where: X is the normal display reading.
m and b are the user entered constants.
Y is the displayed result.

Percent (%)

$$\text{Percent} = \frac{\text{Input - Reference}}{\text{Input}} \times 100\%$$

Where: Input is the normal display reading.
Reference is the user entered constant.
Percent is the displayed result.

dBm

$$\text{dBm} = 10 \log \frac{\left(V_{IN}^{\ 2}/Z_{REF}\right)}{1\text{mW}}$$

Where: V_{IN} is the DC or AC input signal.
Z_{REF} is the specified reference impedance.

dB

$$\text{dB} = 20 \log \frac{|V_{IN}|}{|V_{REF}|}$$

Where: V_{IN} is the DC or AC input signal.
V_{REF} is the specified voltage reference impedance.

Measuring continuity

With this feature, the instrument alerts you with a beep when a resistance reading is below the set level. To measure continuity, press SHIFT and then CONT. Use the ◀, ▶, ▲ and ▼ keys to set the resistance threshold level, and press ENTER. Connect the test leads to INPUT HI and LO.

Testing diodes

With this feature, the instrument measures the forward voltage drop of general-purpose diodes and the zener voltage of zener diodes. To test diodes, press SHIFT and then (⊣). Use the ▲ and ▼ keys to select the test current.

Limit operations

With this feature, you can check to see of readings are within ("IN" displayed), below ("LO" displayed) or above ("HI" displayed) specified low and high reading limits. You can also set the instrument to beep when readings are inside or outside of the limit range.

Setting limits — To set limits (absolute values), press SHIFT and then LIMITS to display the high limit. Use the ◀, ▶, ▲ and ▼ keys to enter the desired value, and press ENTER. Enter the low limit value and again press ENTER.

Enabling limits — Press SHIFT and then ON/OFF to display the beeper status. Use the ▲ and ▼ keys to change the beeper status (NEVER, OUTSIDE or INSIDE) and press ENTER to enable limits. Pressing SHIFT and then ON/OFF a second time disables limit operations.

Reading hold

With this feature, an audible beep is sounded when a valid, settled reading is acquired. A valid reading is determined by the specified window and count.

1. Press SHIFT and then HOLD. Select a window percentage and enter a count.
2. Apply the test probes to the signal and wait for the beeper to sound to indicate a valid reading.
3. Remove the hold condition by lifting the probes.

Pressing SHIFT and then HOLD a second time disables Hold.

Triggers

Factory defaults place the instrument in a continuous (immediate) measurement mode. The instrument can be placed in an external trigger mode where a programmed event is required to cause a measurement (device action).

The instrument is placed in the external trigger mode by pressing the EXT TRIG key. In this mode, a device action (measurement) will occur when the TRIG key is pressed, a bus trigger (*TRG or GET) is received, or an input trigger via the TRIGGER LINK connector is received. After the device action (measurement), an output trigger occurs and is available at the TRIGGER LINK connector. Refer to the User's Manual for details on using the trigger link. Pressing EXT TRIG a second time returns the instrument to continuous operation.

Delay — A programmable delay before the device action (measurement) occurs is available. It can be set manually or an auto delay can be used. To set a delay, press SHIFT and then DELAY. Use the ▲ and ▼ keys to select AUTO or MANual. If MANual is chosen, enter the duration of the delay and press ENTER. The AUTO delay times are listed in Table 3-2 of the User's Manual.

Scan operations

The Model 2000 can be used with an internal scanner card (Model 2000 SCAN or 2001-TCSCAN), or with external scanner cards installed in a switching mainframe (i.e. Model 7001 and 7002).

Step/Scan configuration — A "walk-through" menu is provided to configure stepping or scanning. The main menu is accessed by pressing SHIFT and then CONFIG. Use the ◀, ▶, ▲, ▼ and ENTER keys to select scan type (INTernal or EXTernal), first channel in the scan (MINimum CHANnel), last channel in the scan (MAXimum CHANnel), time between scans, and reading count (RDG CNT).

◀ and ▶ keys — These keys can be used to manually scan through channels on the internal scanner card. Press ▶ to manually increment channels or ◀ to manually decrement channels. Hold down either key to scan continuously.

OPEN and CLOSE keys — Use these keys to open and close channels on the internal scanner card. After pressing CLOSE, use the ◀, ▶, ▲ and ▼ keys to display the desired channel (1 to 10) and press ENTER. Selecting a different channel will cause the previously closed channel to open. For the Ω4 function, CLOSE will close the selected channel and the paired channel. Paired channels for the Model 2000 SCAN are 1&6, 2&7, 3&8, 4&9, and 5&10. Channel pairs are similar for the Model 2001-TCSCAN except that channels 1&6 are not paired.

STEP key — Pressing this key starts a stepping operation of consecutive channels, where output triggers are sent after every channel closure.

SCAN key — Pressing this key starts a scanning operation of consecutive channels, where an output trigger is sent at the end of the scan list.

HALT — Pressing SHIFT and then HALT stops stepping or scanning.

Factory default conditions

Table 2. Factory defaults

Setting	Factory default
Autozero	On
Buffer	No effect
Continuity	
Beeper	On
Digits	4½
Rate	Fast (0.1 PLC)
Threshold	10Ω
Current (AC and DC)	
Digits (AC)	5½
Digits (DC)	6½
Filter	On
Count	10
Mode	Moving average
Range	Auto
Relative	Off
Value	0.0
Rate (AC)	Medium*
Rate (DC)	Medium (1 PLC)
Diode test	
Digits	6½
Range	1mA
Rate	Medium (1 PLC)
Frequency and Period	
Digits	6½
Range	10V
Relative	Off
Value	0.0
Rate	Slow (1 sec)
Function	DCV
GPIB	No effect
Address	(16 at factory)
Language	(SCPI at factory)
Limits	Off
Beeper	Never
High limit	+1
Low limit	-1
mX+b	Off
Scale factor	1.0
Offset	0.0
Percent	Off
References	1.0

Table 2. Factory defaults (cont.)

Setting	Factory default
Resistance (2-wire and 4-wire)	
Digits	6½
Filter	On
Count	10
Mode	Moving average
Range	Auto
Relative	Off
Value	0.0
Rate	Medium (1 PLC)
RS-232	Off
Baud	No effect
Flow	No effect
Tx term	No effect
Scanning	Off
Channels	1-10
Mode	Internal
Temperature	
Digits	5½
Filter	On
Count	10
Mode	Moving average
Junction	Simulated
Temperature	23°C
Relative	Off
Value	0.0
Rate	Medium (1 PLC)
Thermocouple	J
Units	°C
Triggers	
Continuous	On
Delay	Auto
Source	Immediate
Voltage (AC and DC)	
dB reference	No effect
dBm reference	75Ω
Digits (AC)	5½
Digits (DC)	6½
Filter	On
Count	10
Mode	Moving average
Range	Auto
Relative	Off
Value	0.0
Rate (AC)	Medium*
Rate (DC)	Medium (1 PLC)

*DETector:BANDwidth 30

Error and status messages

Table 3. Error and status messages

Number	Description	Event
-440	Query unterminated after indefinite response	EE
-430	Query deadlocked	EE
-420	Query unterminated	EE
-410	Query interrupted	EE
-363	Input buffer overrun	SYS
-350	Queue overflow	SYS
-330	Self-test failed	EE
-314	Save/recall memory lost	EE
-315	Configuration memory lost	EE
-285	Program syntax error	EE
-284	Program currently running	EE
-282	Illegal program name	EE
-281	Cannot create program	EE
-260	Expression error	EE
-241	Hardware missing	EE
-230	Data corrupt or stale	EE
-225	Out of memory	EE
-224	Illegal parameter value	EE
-223	Too much data	EE
-222	Parameter data out of range	EE
-221	Settings conflict	EE
-220	Parameter error	EE
-215	Arm deadlock	EE
-214	Trigger deadlock	EE
-213	Init ignored	EE
-212	Arm ignored	EE
-211	Trigger ignored	EE
-210	Trigger error	EE
-202	Settings lost due to rtl	EE
-201	Invalid while in local	EE
-200	Execution error	EE
-178	Expression data not allowed	EE
-171	Invalid expression	EE
-170	Expression error	EE
-168	Block data not allowed	EE
-161	Invalid block data	EE
-160	Block data error	EE
-158	String data not allowed	EE
-154	String too long	EE
-151	Invalid string data	EE
-150	String data error	EE
-148	Character data not allowed	EE

Table 3. Error and status messages (cont.)

Number	Description	Event
-144	Character data too long	EE
-141	Invalid character data	EE
-140	Character data error	EE
-128	Numeric data not allowed	EE
-124	Too many digits	EE
-123	Exponent too large	EE
-121	Invalid character in number	EE
-120	Numeric data error	EE
-114	Header suffix out of range	EE
-113	Undefined header	EE
-112	Program mnemonic too long	EE
-111	Header separator error	EE
-110	Command header error	EE
-109	Missing parameter	EE
-108	Parameter not allowed	EE
-105	GET not allowed	EE
-104	Data type error	EE
-103	Invalid separator	EE
-102	Syntax error	EE
-101	Invalid character	EE
-100	Command error	EE
+000	No error	SE
+101	Operation complete	SE
+121	Device calibrating	SE
+122	Device settling	SE
+123	Device ranging	SE
+124	Device sweeping	SE
+125	Device measuring	SE
+126	Device calculating	SE
+161	Program running	SE
+171	Waiting in trigger layer	SE
+174	Re-entering the idle layer	SE
+301	Reading overflow	SE
+302	Low limit 1 event	SE
+303	High limit 1 event	SE
+304	Low limit 2 event	SE
+305	High limit 2 event	SE
+306	Reading available	SE
+307	Voltmeter complete	SE
+308	Buffer available	SE
+309	Buffer half full	SE
+310	Buffer full	SE
+311	Buffer overflow	SE

Table 3. Error and status messages (cont.)

Number	Description	Event
	Calibration messages:	
+400	10 vdc zero error	EE
+401	100 vdc zero error	EE
+402	10 vdc full scale error	EE
+403	-10 vdc full scale error	EE
+404	100 vdc full scale error	EE
+405	-100 vdc full scale error	EE
+406	1k 2-w zero error	EE
+407	10k 2-w zero error	EE
+408	100k 2-w zero error	EE
+409	10M 2-w zero error	EE
+410	10M 2-w full scale error	EE
+411	10M 2-w open error	EE
+412	1k 4-w zero error	EE
+413	10k 4-w zero error	EE
+414	100k 4-w zero error	EE
+415	10M 4-w sense lo zero error	EE
+416	1k 4-w full scale error	EE
+417	10k 4-w full scale error	EE
+418	100k 4-w full scale error	EE
+419	1M 4-w full scale error	EE
+420	10M 4-w full scale error	EE
+421	10m adc zero error	EE
+422	100m adc zero error	EE
+423	10m adc full scale error	EE
+424	100m adc full scale error	EE
+425	1 adc full scale error	EE
+438	Date of calibration not set	EE
+439	Next date of calibration not set	EE
+450	100m vac dac error	EE
+451	1 vac dac error	EE
+452	10 vac dac error	EE
+453	100 vac dac error	EE
+454	100m vac zero error	EE
+455	100m vac full scale error	EE
+456	1 vac zero error	EE
+457	1 vac full scale error	EE
+458	1 vac noise error	EE
+459	10 vac zero error	EE
+460	10 vac full scale error	EE
+461	10 vac noise error	EE
+462	100 vac zero error	EE
+463	100 vac full scale error	EE
+464	750 vac zero error	EE
+465	750 vac full scale error	EE
+466	750 vac noise error	EE

Table 3. Error and status messages (cont.)

Number	Description	Event
+467	Post filter offset error	EE
+468	1 aac zero error	EE
+469	1 aac full scale error	EE
+470	3 aac zero error	EE
+471	3 aac full scale error	EE
+472	Input time constant error	EE
+473	Frequency gain error	EE
+500	Calibration data invalid	EE
+510	Reading buffer data lost	EE
+511	GPIB address lost	EE
+512	Power-on state lost	EE
+513	AC calibration data lost	EE
+514	DC calibration data lost	EE
+515	Calibration dates lost	EE
+522	GPIB communication language lost	EE
+610	Questionable Calibration	SE
+611	Questionable Temperature	SE
+800	RS-232 Framing Error detected	EE
+802	RS-232 Overrun detected	EE
+803	RS-232 Break detected	EE
+805	Invalid system communication	EE
+806	RS-232 Settings Lost	EE
+807	RS-232 OFLO: Characters Lost	EE
+808	ASCII only with RS-232	EE
+900	Internal System Error	EE
	DDC Status Model:	
+950	DDC Trigger Overrun Error	EE
+951	DDC Interval Overrun Error	EE
+952	DDC Big String Error	EE
+953	DDC Uncalibrated Error	EE
+954	DDC No Scanner Error	EE
+955	DDC Maximum Channel is 4	EE
+956	DDC Maximum Channel is 8	EE
+957	DDC Calibration Locked	EE
+958	DDC Conflict Error	EE
+959	DDC No Remote Error	EE
+960	DDC Mode IDDC Error	EE
+961	DDC Mode IDDCO Error	EE
	Keithley 199 Serial Poll Byte Events:	
+962	DDC Ready	SE
+963	DDC Reading Done	SE
+964	DDC Buffer Half Full	SE
+965	DDC Buffer Full	SE
+966	DDC Reading overflow	SE

Table 3. Error and status messages (cont.)

Number	Description	Event
	Fluke 8842 serial poll byte events:	
+970	Fluke Error	SE
+971	Data Available	SE
+972	Overrange	SE

EE = error event
SE = status event
SYS = system error event

Remote Operation Summary

At the factory, the instrument is set for GPIB bus operation at primary address 16 using the SCPI programming language.

GPIB bus — Use the GPIB bus configuration menu to enable or disable GPIB bus operation (ON or OFF), and to check and/or change the primary address (0 to 30) and language (SCPI, 199, or 8842). The configuration menu is accessed by pressing SHIFT and then GPIB. Commands for the SCPI language are provided in Tables 4 through 15. The DDC commands for the 199 and 8842 languages are provided in Tables 16 and 17.

RS-232 interface — Use the RS-232 interface menu to enable or disable RS-232 interface operation (ON or OFF), and to check and/or change the baud rate (300 to 19.2k), flow control (NONE or XonXoFF) and terminator (LF, CR or LFCR). Note that only the SCPI language commands can be used over the RS-232 interface.

Status structure

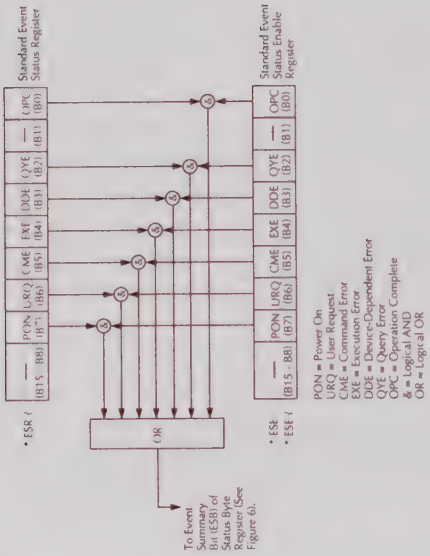

Figure 2. Standard event status

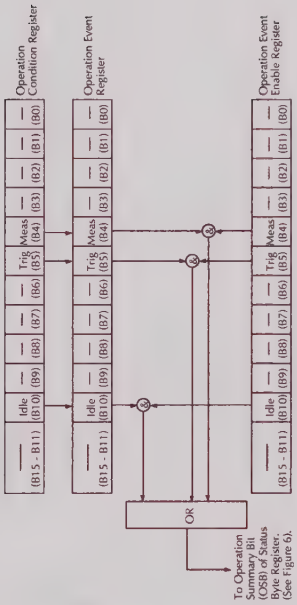

Figure 3. Operation event status

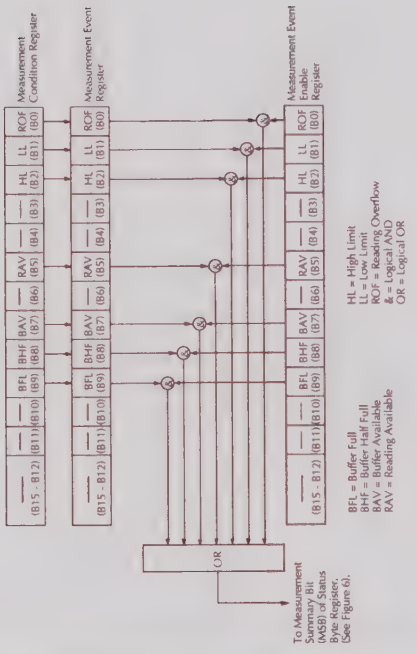

Figure 4. Measurement event status

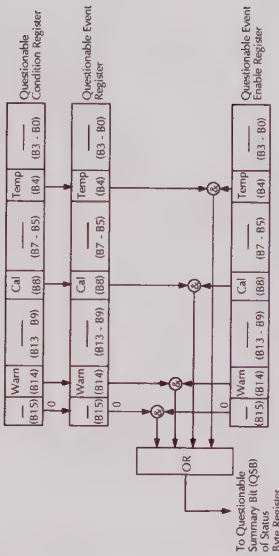

Figure 5. Questionable event status

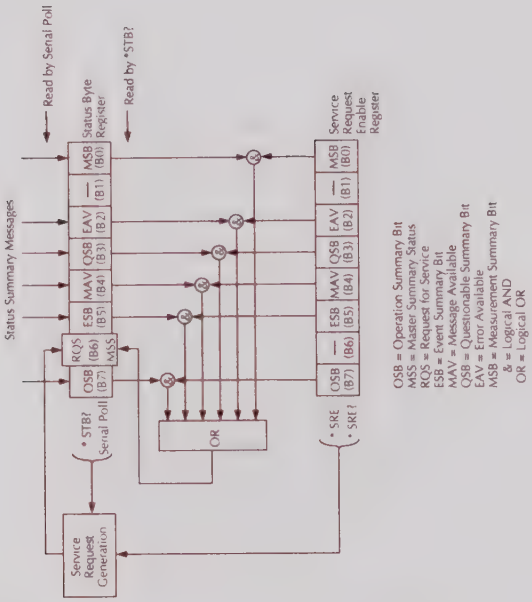

Figure 6. Status byte and service request (SRQ)

IEEE-488.2 common commands and queries

Table 4. IEEE-488.2 common commands and queries

Mnemonic	Name	Description
*CLS	Clear status	Clears all event registers and Error Queue.
*ESE <NRf>	Event enable command	Program the Standard Event Enable Register.
*ESE?	Event enable query	Read the Standard Event Enable Register.
*ESR?	Event status register query	Read the Standard Event Enable Register and clear it.
*IDN?	Identification query	Returns the manufacturer, model number, serial number and firmware revision levels of the unit.
*OPC	Operation complete command	Set the Operation Complete bit in the Standard Event Status Register after all pending commands have been executed.
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.
*OPT?	Option identification query	Returns an ID code that indicates which memory option is installed and whether or not the optional scanner card is installed.
*RCL <NRf>	Recall command	Returns the Model 2000 to the setup configuration stored in the specified memory location.
*RST	Reset command	Returns the Model 2000 to the *RST default conditions.
*SAV <NRf>	Save command	Saves the current setup to the specified memory location.

Table 4. IEEE-488.2 common commands and queries (cont.)

Mnemonic	Name	Description
*SRE <NRf>	Service request enable command	Programs the Service Request Enable Register.
*SRE?	Service request enable query	Reads the Service Request Enable Register.
*STB?	Read status byte query	Reads the Status Byte Register.
*TRG	Trigger command	Sends a bus trigger to the 2000.
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.
*WAI	Wait-to-continue command	Wait until all previous commands are executed.

SCPI command subsystems

Notes:

1. Brackets ([]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.
2. Angle brackets (<>) are used to indicate parameter type. Do not use angle brackets in the program message.
3. Upper case characters indicate the short-from version for each command word.

Table 5. Signal oriented measurement commands

Command	Description
:CONFigure:<function>	Places the Model 2000 in a "one-shot" measurement mode for the specified function.
:FETCh?	Requests the latest reading.
:READ?	Performs an :ABORt, :INITiate, and a :FETCh?.
MEASure[:<function>]?	Performs an :ABORt, :CONFigure:<function>, and a :READ?.

Table 6. CALCulate command summary

Command	Description
:CALCulate[1]	Subsystem to control CALC 1:
:FORMat <name>	Select math format (NONE, MXB, PERCent).
:FORMat?	Query math format.
:KMATh	Path to configure math calculations:
:MMFactor <NRf>	Set "m" factor for mx+b (-100e6 to 100e6).
:MMFactor?	Query "m" factor.
:MBFactor <NRf>	Set "b" factor for mx+b (-100e6 to 100e6).
:MBFactor?	Query "b" factor.
:MUNits <name>	Specify units for mx+b reading (three characters 'A' through 'Z').
:MUNits?	Query "mx+b" units.
:PERCent <NRf>	Set target value for PERCent calculation (-100e6 to 100e6).
:ACQuire	Use input signal as target value.
:PERCent?	Query percent.
:STATe <b>	Enable or disable kmath calculation.
:STATe?	Query state of kmath function.
:DATA?	Read result of kmath calculation.
:CALCulate2	Subsystem to control CALC 2:
:FORMat <name>	Select math format: (MEAN, SDEViation, MAXimum, MINimum, or NONE).
:FORMat?	Query math format.
:STATe <b>	Enable or disable calculation.
:STATe?	Query state of math function.
:IMMediate	Recalculate raw input data in buffer.
:IMMediate?	Perform calculation and read result.
:DATA?	Read math result of CALC 2.

Table 6. CALCulate command summary (cont.)

Command	Description
:CALCulate3	Subsystem to control CALC 3 (limit test):
:LIMit[1]	Path to control LIMIT 1 test:
:UPPer	Path to configure upper limit:
[:DATA] <n>	Set upper limit (-100e6 to 100e6).
[:DATA]?	Query upper limit.
:LOWer	Path to configure lower limit:
[:DATA] <n>	Set lower limit (-100e6 to 100e6).
[:DATA]?	Query lower limit.
:STATe <b>	Enable or disable limit test.
:STATe?	Query state of limit test.
:FAIL?	Query test result (1 = pass, 0 = fail).
:CLEAR	Path to clear failed test:
[:IMMediate]	Clear failed test indication.
:AUTO <b>	Enable or disable auto clear.
:AUTO?	Query auto clear.
:IMMediate	Re-perform limit tests.

Table 7. DISPlay command summary

Command	Description
:DISPlay	
[:WINDow[1]]	
:TEXT	Path to control user text messages.
:DATA <a>	Define ASCII message "a" (up to 12 characters).
:DATA?	Query text message.
:STATe <b>	Enable or disable message mode.
:STATe?	Query text message state.
:ENABle <b>	Enable or disable the front panel display.
:ENABle?	Query state of the display.

Table 8. FORMat command summary

Command	Description
:FORMat	
[:DATA] <type>[,<length>]	Select data format: (ASCii, SREal or DREal).
[:DATA]?	Query data format.
:ELEMents <item list>	Specify data elements: (READing, CHANnel, and UNITs).
:ELEMents?	Query data elements.
:BORDer <name>	Select binary byte order: (NORMal or SWAPped).
:BORDer?	Query byte order.

Table 9. ROUTe command summary

Command	Description
:ROUTe	Commands to control scanner card:
:CLOSe <chan num>	Close specified channel (1 to 10) or channel pair (1 to 5).
:STATe?	Query closed channel (or channel pair).
:OPEN:ALL	Open all input channels (1 through 10).
:MULTiple	Path to close and open multiple channels:
:CLOSe <list>	Close specified channels (1 to 11).
:STATe?	Query closed channel.
:OPEN <list>	Open specified channels (1 to 11).
:SCAN	Path to scan channels.
[:INTernal] <list>	Specify internal scan list (2 to 10 channels).
[:INTernal]?	Query internal scan list.
:EXTernal <list>	Specify external scan list (2 to 800 channels).
:EXTernal?	Query external scan list.
:LSELect <name>	Select scan operation (INTernal, EXTernal, or NONE).
:LSELect?	Query scan operation.

Table 10. SENSe command summary

Command	Description
[:SENSe[1]]	
:FUNCtion <name>	Select measurement function: 'VOLTage:AC', VOLTage :DC', RESistance', 'FRESistance', 'CURRent:AC', 'CURRent: DC' , 'FREQuency','TEMPerature', 'PERiod', 'DIODe', "CONTinuity'.
:FUNCtion?	Query function.
:DATA?	Return the last instrument reading.
:FRESh?	Returns a new (fresh) reading.
:HOLD	Path to control Hold feature:
:WINDow <NRf>	Set Hold window (%); 0.01 to 20.
:WINDow?	Query Hold window.
:COUNt <NRf>	Set Hold count; 2 to 100.
:COUNt?	Query Hold count.
:STATe <NRf>	Enable or disable Hold.
:STATe?	Query state of Hold.
:CURRent:AC	Path to configure AC current.
:NPLCycles <n>	Set integration rate (line cycles; 0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (0 to 3.1).
[:UPPer]?	Query range.
:AUTO <b>	Enable or disable auto range.
:AUTO?	Query auto range.
:REFerence <n>	Specify reference (-3.1 to 3.1).
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:AVERage	Path to configure and control the filter.
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.

Table 10. SENSe command summary (cont.)

Command	Description
:*CURRent:AC*	
:DETector	Path to configure bandwidth:
:BANDwidth <NRf>	Specify bandwidth (3 to 300e3).
:BANDwidth?	Query bandwidth.
:CURRent:DC	Path to configure DC current.
:NPLCycles <n>	Set integration rate (line cycles; 0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (0 to 3.1).
[:UPPer]?	Query range.
:AUTO <b>	Enable or disable auto range.
:AUTO?	Query auto range.
:REFerence <n>	Specify reference (-3.1 to 3.1).
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:AVERage	Path to configure and control the filter.
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.
:VOLTage:AC	Path to configure AC voltage.
:NPLCycles <n>	Set integration rate (line cycles; 0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (0 to 757.5).
[:UPPer]?	Query range.
:AUTO <b>	Enable or disable auto range.
:AUTO?	Query auto range.
:REFerence <n>	Specify reference (-757.5 to 757.5).

Table 10. SENSe command summary (cont.)

Command	Description
:VOLTage:AC	
:REFerence <n>	
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:AVERage	Path to configure and control the filter.
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.
:DETector	Path to configure bandwidth:
:BANDwidth <NRf>	Specify bandwidth (3 to 300e3).
:BANDwidth?	Query bandwidth.
:VOLTage:DC	Path to configure DC voltage:
:NPLCycles <n>	Set integration rate (line cycles; (0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (0 to 1010).
[:UPPer]?	Query range.
:AUTO <b>	Enable or disable auto range.
:AUTO?	Query auto range.
:REFerence <n>	Specify reference (-1010 to +1010).
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference (0 or 1).
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.

Table 10. SENSe command summary (cont.)

Command	Description
:VOLTage:DC	
:AVERage	Path to configure and control the filter.
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.
:RESistance	Path to configure resistance:
:NPLCycles <n>	Set integration rate (line cycles; 0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (0 to 120e6).
[:UPPer]?	Query range.
:AUTO <b>	Enable or disable auto range.
:AUTO?	Query auto range.
:REFerence <n>	Specify reference (0 to 120e6).
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:AVERage	Path to configure and control filter.
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.

Table 10. SENSe command summary (cont.)

Command	Description
:FRESistance	Path to configure four-wire resistance:
:NPLCycles <n>	Set integration rate (line cycles; 0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (0 to 101e6).
[:UPPer]?	Query range.
:AUTO <b>	Enable or disable auto range.
:AUTO?	Query auto range.
:REFerence <n>	Specify reference (0 to +101e6).
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:AVERage	Path to configure and control filter.
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.
:TEMPerature	Path to configure temperature:
:NPLCycles <n>	Set integration rate (line cycles; 0.01 to 10).
:NPLCycles?	Query line cycle integration rate.
:REFerence <n>	Specify reference; -200 to 1372.
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:AVERage	Path to configure and control the filter.

Table 10. SENSe command summary (cont.)

Command	Description
:TEMPerature	
:AVERage	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).
:TCONtrol?	Query filter type.
:COUNt <n>	Specify filter count (1 to 100).
:COUNt?	Query filter count.
:STATe <b>	Enable or disable filter.
:STATe?	Query state of digital filter.
:TCouple	Path to configure thermocouple:
:TYPE <name>	Select thermocouple type (J, K, or T).
:TYPE?	Query thermocouple type.
:RJUNction	Path to configure reference junction:
:RSELect <name>	Select reference type (SIMulated or REAL).
:RSELect?	Query reference type.
:SIMulated <n>	Specify simulated temperature in °C (0 to 50).
:SIMulated?	Query simulated temperature.
:REAL	Path to configure real reference junction:
:TCOefficient <n>	Specify temp coefficient (-0.09999 to 0.09999).
:TCOefficient?	Query temp coefficient.
:OFFSET <n>	Specify voltage offset at 0°C (-0.09999 to 0.09999).
:OFFSet?	Query voltage offset.

Table 10. SENSe command summary (cont.)

Command	Description
:FREQuency	Path to configure frequency.
:APERture	Sets gate time for period measurements (0.01-1.0s).
:APERture?	Query period gate time.
:THReshold	Path to select the threshold voltage range:
:VOLTage	
:RANGe <n>	Select threshold range (0 to 1010).
:RANGe?	Query threshold range.
:REFerence <n>	Specify reference (0 to 1.5e7)
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:PERiod	Path to configure period.
:APERture	Sets gate time for period measurements (0.01-1.0s).
:APERture?	Query period gate time.
:THReshold	Path to select the threshold voltage range:
:VOLTage	
:RANGe <n>	Select threshold range (0 to 1010).
:RANGe?	Query threshold range.
:REFerence <n>	Specify reference (0 to 1).
:STATe <b>	Enable or disable reference.
:STATe?	Query state of reference.
:ACQuire	Use input signal as reference.
:REFerence?	Query reference value.
:DIGits <n>	Specify measurement resolution (4 to 7).
:DIGits?	Query resolution.
:DIODe	Paths to configure diode test:
:CURRent	
:RANGe	Path to select range.
[:UPPer] <NRf>	Select range (0 to 1e-3)
[:UPPer]?	Query range.

Table 10. SENSe command summary (cont.)

Command	Description
:CONTinuity	Path to configure continuity test:
:THReshold <NRf>	Set threshold resistance (1 to 1000).
:THReshold?	Query threshold resistance.

Table 11. STATus command summary

Command	Description
:STATus	
:MEASurement	Path to control measurement event registers:
[:EVENt]?	Read the event register.
:ENABle <NRf>	Program the enable register.
:ENABle?	Read the enable register.
:CONDition?	Read the condition register.
:OPERation	Path to control operation status registers:
[:EVENt]?	Read the event register.
:ENABle <NRf>	Program the enable register.
:ENABle?	Read the enable register.
:CONDition?	Read the condition register.
:QUEStionable	Path to control questionable status registers:
[:EVENt]?	Read the event register.
:ENABle <NRf>	Program the enable register.
:ENABle?	Read the enable register.
:CONDition?	Read the condition register.
:PRESet	Return status registers to default states.
:QUEue	Path to access error queue:
[:NEXT]?	Read the most recent error message.
:ENABle <list>	Specify error and status messages for queue.
:ENABle?	Read the enabled messages.
:DISable <list>	Specify messages not to be placed in queue.
:DISable?	Read the disabled messages.
:CLEar	Clears all messages from Error Queue.

Table 12. SYSTem command summary

Command	Description
:SYSTem	
:PRESet	Return to :SYST:PRES defaults.
:POSetup <name>	Select power-on setup: (RST, PRESet or SAV0).
:POSetup?	Query power-on setup.
:FRSWitch?	Query INPUTS switch (0=rear, 1=front).
:VERSion?	Query rev level of SCPI standard.
:ERRor?	Query (read) Error Queue.
:AZERo	Path to set up autozero.
:STATe <b>	Enable or disable autozero.
:STATe?	Query autozero.
:KEY <NRf>	Simulate key-press (1 to 31; see Figure 5-10 of the User's Manual).
:KEY?	Query the last "pressed" key.
:CLEar	Clears messages from the Error Queue.
:BEEPer	Path to control beeper.
[:STATe] <b>	Enable or disable beeper.
[:STATe]?	Query state of beeper.
:LOCal	Take 2000 out of remote and restore operation of front panel controls (RS-232 only).
:REMote	Place 2000 in remote (RS-232 only).
:RWLock	Lockout front panel controls (RS-232 only).
:KCLick <b>	Turn the keyclick on/off.
:KCLick	Query the keyclick status.
:LFRequency?	Query power line frequency.

Table 13. TRACe command summary

Command	Description
:TRACe|:DATA	Use :TRACe or :DATA as root command.
:CLEar	Clear readings from buffer.
:FREE?	Query bytes available and bytes in use.
:POINts <NRf>	Specify size of buffer (2 to 1024).
:POINts?	Query buffer size.
:FEED <name>	Select source of readings (SENSe[1], CALCulate[1], NONE.
:CONTrol <name>	Select buffer control mode (NEVer or NEXT)
:CONTrol?	Query buffer control mode.
:FEED?	Query source of readings for buffer.
:DATA?	Read all readings in the buffer.

Table 14. Trigger command summary

Command	Description
:INITiate	Subsystem command path:
[:IMMediate]	Initiate one trigger cycle.
:CONTinuous <b>	Enable or disable continuous initiation.
:CONTinuous?	Query continuous initiation.
:ABORt	Reset trigger system.
:TRIGger[:SEQuence[1]]	Path to program Trigger Layer:
:COUNt <n>	Set measure count (1 to 9999, or INF).
:COUNt?	Query measure count.
:DELay <n>	Set delay (0 to 999999.999 sec)
:AUTO <b>	Enable or disable auto delay.
:AUTO?	Query state of delay.
:DELay?	Query delay.
:SOURce <name>	Select control source (IMMediate, TIMer, MANual, BUS, or EXTernal).
:SOURce?	Query control source.
:TIMer <n>	Set timer interval (0 to 999999.999 sec).
:TIMer?	Request the programmed timer interval.
:SIGNal	Loop around control source.
:SAMPle	
:COUNt <NRf>	Specify sample count (1 to 1024).
:COUNt?	Query sample count.

Table 15. TEMPerature command summary

Command	Description
:UNIT	
:TEMPerature <name>	Select temperature measurement units (C, F, or K).
:TEMPerature?	Query temperature units.
:VOLTage	Path to configure voltage units.
:AC <name>	Select ACV measurement units (V, DB or DBM).
:DB	Path to set DB reference voltage.
:REFerence <n>	Specify reference in volts ($1e^{-7}$ to 1000).
:REFerence?	Query DB reference.
:DBM	Path to set DBM reference impedance.
:IMPedance <n>	Specify reference impedance (1 to 9999).
:IMPedance?	Query DBM reference impedance.
:AC?	Query ACV units.
[:DC] <name>	Select DCV measurement units (V, DB, or DBM)
:DB	Path to set DB reference voltage:
:REFerence <n>	Specify reference in volts (0 to 1000).
:REFerence?	Query reference.
:DBM	Path to set DBM refernece impedance:
:IMPedance <n>	Specify reference impedance ($1e^{-7}$ to 9999).
:IMPedance?	Query reference impedance.
:DC?	Query DCV units.

Models 196/199 and 8840A/8842A commands

Table 16. Models 196/199 device-dependent command summary

Mode	Command	Description
Execute	X	Execute other device-dependent commands.
Function	F0	DC volts
	F1	AC volts
	F2	2-wire ohms
	F3	DC current
	F4	AC current
	F5	ACV dB
	F6	Not valid
	F7	Frequency
	F8	Temperature
	F9	4-wire ohms
Range		

	DCV	ACV	DCA	ACA	Ohms*	ACV dB	Freq
R0	Auto	Auto	Auto	Auto	Auto	Auto	—
R1	1V	1V	100mA	1A	1kΩ	1V	0.1V
R2	10V	10V	3A	3A	10kΩ	10V	1V
R3	100V	100V	3A	3A	100kΩ	100V	10V
R4	1000V	750V	3A	3A	1MΩ	750V	100V
R5	1000V	750V	3A	3A	10MΩ	750V	750V
R6	1000V	750V	3A	3A	100MΩ	750V	—
R7	1000V	750V	3A	3A	100MΩ	750V	—

*2-wire and 4-wire ohms

Zero (rel)	Z0	Zero disabled
	Z1	Zero enabled
	Z2	Zero enabled using a zero value (V)
Filter	P0	Filter disabled
	P1	Moving filter (count = 10)
	P2	Repeat filter (count = 10)
Rate	S0	0.1 PLC integration
	S1	Line cycle integration (16.67msec, 60Hz; 20msec, 50Hz)
	S2	10 PLC (166.67msec integration, 60Hz; 200msec integration, 50Hz)

Table 16. Models 196/199 device-dependent command summary (cont.)

Mode	Command	Description
Trigger mode	T0	Continuous on Talk
	T1	One-shot on Talk
	T2	Continuous on GET
	T3	One-shot on GET
	T4	Continuous on X
	T5	One-shot on X
	T6	Continuous on External Trigger
	T7	One-shot on External Trigger
Reading mode	B0	Readings from A/D converter
	B1	Individual readings from data store
	B2	All readings from data store (buffer dump)
Data store size	I0	Disable data store
	In	Data store of n (n=1 to 500), fill and stop
Interval	Q0	Default interval, 175msec (SELECT OFF)
	Qn	n=interval in milliseconds (15msec to 999999msec)
Value	V±nn.nnnn or V±n.nnnnnnE+n	Zero value, simulated reference junction temperature
Default conditions	L0	Restore factory default conditions and save (L1)
	L1	Save present machine states as default conditions
Data format	G0	Reading with prefix.
	G1	Reading without prefix.
	G2	Reading and buffer location with prefix.
	G3	Reading and buffer location without prefix.
	G4	Reading and channel with prefix.
	G5	Reading and channel without prefix.
	G6	Reading, buffer location, and channel with prefix.
	G7	Reading, buffer location, and channel without prefix.

Table 16. Models 196/199 device-dependent command summary (cont.)

Mode	Command	Description
SRQ	M0	Disable
	M1	Reading overflow
	M2	Data store full
	M4	Data store half full
	M8	Reading done
	M16	Ready
	M32	Error
EOI and bus hold-off	K0	Enable EOI and bus hold-off on X
	K1	Disable EOI, enable bus hold-off on X
	K2	Enable EOI, disable bus hold-off on X
	K3	Disable both EOI and bus hold-off on X
Terminator	Y0	CR LF
	Y1	LF CR
	Y2	CR
	Y3	LF
Status	U0	Send machine status word (199 format only)
	U1	Send error conditions (only supports no scanner, IDDC, IDDCO)
	U2	Send Translator word list (since Translator is not supported, replies with one space character)
	U3	Send buffer size
	U4	Send current value of "V" (199 format, equivalent to U7 for 196)
	U5	Send input switch status (front /rear) (199 format, equivalent to U8 for 196)
	U6	Send simulated temperature (set by H0)
Multiplex	A0	Auto/Cal multiplex disabled
	A1	Auto/Cal multiplex enabled
Delay	Wn	n=delay period in milliseconds, (0msec to 999999msec)

Table 16. Models 196/199 device-dependent command summary (cont.)

Mode	Command	Description
Display	Da	Display up to 12-character message (a=character)
	D	Cancel display mode
Scanning	N0	Open all - stop scanning or stepping if applicable
	N1	Close channel 1
	N2	Close channel 2
	N3	Close channel 1
	N4	Close channel 4
	N5	Close channel 5
	N6	Close channel 6
	N7	Close channel 7
	N8	Close channel 8
	N9	Close channel 9
	N10	Close channel 10
	N11	Step mode, max channel is 2
	N12	Step mode, max channel is 3
	N13	Step mode, max channel is 4
	N14	Step mode, max channel is 5
	N15	Step mode, max channel is 6
	N16	Step mode, max channel is 7
	N17	Step mode, max channel is 8
	N18	Step mode, max channel is 9
	N19	Step mode, max channel is 10
	N20	Open all - stop scanning or stepping if applicable
	N21	Scan mode, max channel is 2
	N22	Scan mode, max channel is 3
	N23	Scan mode, max channel is 4
	N24	Scan mode, max channel is 5
	N25	Scan mode, max channel is 6
	N26	Scan mode, max channel is 7
	N27	Scan mode, max channel is 8
	N28	Scan mode, max channel is 9
	N29	Scan mode, max channel is 10

Table 16. Models 196/199 device-dependent command summary (cont.)

Mode	Command	Description
Thermocouple	J0	Type J thermocouple
	J1	Type K thermocouple
	J2	Type T thermocouple
	O0	Simulated reference junction (for temperature function)
	O1	Real reference junction (for temperature function)
	H0	Set simulated reference junction temperature using "V" command; 0 to 50 (°C).

Table 17. Models 8840A/8842A device-dependent command summary

Mode	Command	Description
Function	F1	VDC (default)
	F2	VAC
	F3	2-wire kΩ
	F4	4-wire kΩ
	F5	mA DC
	F6	mA AC
	F7	Freq
	F8	Temp
Range		

	VDC	VAC	kΩ*	mA DC	mA AC	Freq
R0	**	**	**	**	**	—
R1	1V	1V	1kΩ	10mA	3A	1V
R2	10V	10V	10kΩ	10mA	3A	10V
R3	100V	100V	100kΩ	100mA	3A	100V
R4	1000V	750V	1MΩ	1A	1A	750V
R5	1000V	750V	10MΩ	3A	3A	750V
R6	1000V	750V	100MΩ	3A	3A	750V
R7	***	***	***	***	***	—
R8	100mV	750V	100Ω	3A	3A	750V

*2-wire and 4-wire ohms
**Auto on
***Auto off

Reading rate	S0	Slow, 10 PLC
	S1	Medium, 1 PLC, 6½-digit resolution (default)
	S2	Fast, 0.1 PLC, 5½-digit resolution
Trigger mode		

	Trigger mode	Rear panel trigger	Auto delay
T0 (default)	Internal	Disabled	—
T1	External	Enabled	On
T2	External	Disabled	On
T3	External	Enabled	Off
T4	External	Disabled	Off

Note: Delay is enabled by entering EXT TRIG mode while in local.

Offet (Rel)	B0	Offset off (default)
	B1	Offset on
Display	D0	Normal display (default)
	D1	Blank display

Table 17. Models 8840A/8842A device-dependent command summary (cont.)

Mode	Command	Description
Suffix	Y0	Disable output suffix (default)
	Y1	Enable output suffix
Terminator	W0	Enable CR LF EOI (default)
	W1	Enable CR LF only
	W2	Enable CR EOI only
	W3	Enable CR only
	W4	Enable LF EOI only
	W5	Enable LF only
	W6	Enable EOI only
	W7	Disable all output terminators
Clear	*	Device clear (resets 8842A to default conditions)
	X0	Clear error register
Single-trigger	?	Trigger measurement
GET	G0	Get instrument configuration (function, range, speed, trigger)
	G1	Get SRQ mask
	G2	Get calibration input prompt (generates error message 51)
	G3	Get user-defined message (replies with 16 space characters)
	G4	Get calibration status (replies with "1000")
	G5	Get IAB status (input F/R, autorange on/off, offset on/off)
	G6	Get YW status (suffix enabled/disabled, terminator selection)
	G7	Get error status
	G8	Get instrument ID (replies with "FLUKE,8842A,0,EMUL")
	G9	Get status of JKM commands (temp. units; TC type and junction) String = 1jkm

Table 17. Models 8840A/8842A device-dependent command summary (cont.)

Mode	Command	Description
GET (cont.)	G10	Get closed channel number String = 10nn Where: nn = 00 (all open) 01 through 10 (closed channel)
	G11	Get simulated reference junction temperature String = xx.xxx (in °C) Note: G2 valid only in calibration mode.
PUT	P0	Put instrument configuration (function, range, speed, trigger)
	P1	Put SRQ mask
	P4	Set simulated junction temperature; 0 to 50 (°C) Default temperature = 23°C
PUT format	N <value> P0 N <value> P1 N <value> P4	
Thermocouple type	K0	Type J thermocouple (default)
	K1	Type K thermocouple
	K2	Type T thermocouple
Temperature unit	J0	°C (default)
	J1	K
	J2	°F
Thermocouple reference junction	M0	Select simulated junction (default)
	M1	Select real junction (channel 1 for 2001-TCSCAN card)

Table 17. Models 8840A/8842A device-dependent command summary (cont.)

Mode	Command	Description
Scanner channel	Ln	Control specified channel of internal scan card where: n = 0 (Open all channels) 1 through 10 (close specified channel) Note: For 4-wire ohms, only channels 1 through 5 are valid due to automatic channel pairing.
SRQ mask values	00 01 16 32	SRQ disabled (default) SRQ on overrange SRQ on data available SRQ on any error Note: Add SRQ mask values for combinations. Example: 33 for SRQ on overrange or any error.

KEITHLEY

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Model 2000 Multimeter
Calibration Manual

A GREATER MEASURE OF CONFIDENCE

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 3 years from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

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Model 2000 Multimeter
Calibration Manual

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a ⏚ screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The ⚠ symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The ⚠ symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Table of Contents

1 Performance Verification

Introduction....1-2
Verification test requirements....1-3
Performing the verification test procedures....1-6
Verifying DC voltage....1-7
Verifying AC voltage....1-8
Verifying DC current....1-10
Verifying AC current....1-11
Verifying resistance....1-12

2 Calibration

Introduction....2-2
Environmental conditions....2-3
Calibration considerations....2-4
Calibration code....2-5
Comprehensive calibration....2-6
Front panel calibration....2-7
SCPI command calibration....2-14

3 Calibration Command Reference

Introduction....3-2
Command summary....3-4
Miscellaneous calibration commands....3-6
DC calibration commands....3-10
AC calibration commands....3-16
Manufacturing calibration....3-18
Bus error reporting....3-19
Detecting calibration step completion....3-20

A Specifications

Accuracy calculations....A-7
Optimizing measurement accuracy....A-10
Optimizing measurement speed....A-11

B Error Messages

C Calibration Program

List of Illustrations

1 Performance Verification

Connections for DC volts verification 1-7
Connections for AC volts verification 1-8
Connections for DC current verification 1-10
Connections for AC current verification 1-11
Connections for resistance verification (100Ω-10MΩ ranges) 1-12
Connections for resistance verification (100MΩ range) 1-13

2 Calibration

Low-thermal short connections 2-8
Calibrator connections for DC volts and ohms portion of comprehensive calibration 2-9
Connections for DC and AC amps comprehensive calibration 2-11
Connections for AC volts calibration 2-12
Synthesizer connections for manufacturing calibration 2-21

List of Tables

1 Performance Verification

Recommended verification equipment 1-4
DCV reading limits 1-7
ACV reading limits 1-9
DCI limits 1-10
ACI limits 1-11
Limits for resistance verification 1-13

2 Calibration

Recommended equipment for comprehensive, DC only, or AC only calibration 2-6
Comprehensive calibration procedures 2-7
DC volts calibration summary 2-10
Ohms calibration summary 2-10
DC current calibration summary 2-11
Connections for AC volts calibration 2-12
AC current calibration summary 2-13
DC voltage calibration programming steps 2-16
Resistance calibration programming steps 2-16
DC current calibration programming steps 2-17
AC voltage calibration programming steps 2-18
AC current calibration programming steps 2-19
Recommended equipment for manufacturing calibration 2-20

3 Calibration Command Reference

Calibration command summary 3-4
DC calibration commands 3-10
AC calibration commands 3-16

B Error Messages

Error summary B-2

1
Performance Verification

Introduction

Use the procedures in this section to verify that the Model 2000 Multimeter accuracy is within the limits stated in the instrument's one-year accuracy specifications. You can perform verification procedures:

- When you first receive the instrument to make sure that it was not damaged during shipment, and that the unit meets factory specifications.
- When a question exists about the instrument's accuracy.
- Following calibration.

WARNING ***The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.***

NOTE *If the instrument is still under warranty and its performance is outside specified limits, contact your Keithley representative or the factory to determine the correct course of action.*

This section includes the following information:

- **Verification test requirements:** Explains the test requirements.
- **Performing the verification procedures:** Provides general information about the test procedures.
- **Verifying DC voltage:** Provides the procedure to verify that the instrument meets its DC voltage accuracy specifications.
- **Verifying AC voltage:** Provides the procedure to verify AC voltage measurement accuracy.
- **Verifying DC current:** Outlines the procedure to test DC current measurement accuracy.
- **Verifying AC current:** Provides the procedure to verify AC current measurement accuracy.
- **Verifying resistance:** Provides the procedure to test resistance measurement accuracy.

Verification test requirements

Be sure that you perform the verification tests:

- Under the proper environmental conditions.
- After the specified warm-up period.
- Using the correct line voltage.
- Using the proper calibration equipment.
- Using the specified reading limits.

Environmental conditions

Conduct your performance verification procedures in a test environment that has:

- An ambient temperature of 18-28°C (65-82°F).
- A relative humidity of less than 80% unless otherwise noted.

Line power

The Model 2000 Multimeter requires a line voltage of 100V/120V/220V/240V, ±10% and a line frequency of 45Hz to 66Hz, or 360Hz to 440Hz.

Warm-up period

Allow the Model 2000 Multimeter to warm up for at least one hour before conducting the verification procedures.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Recommended test equipment

Table 1-1 summarizes recommended verification equipment. Use the Fluke Model 5700A Calibrator (or the equivalent) to verify Model 2000 Multimeter measurement accuracy.

You can use alternate equipment as long as that equipment has specifications at least as good as those listed in Table 1-1. Keep in mind, however, that the calibrator will add to the uncertainty of each measurement. Table 1-1 lists the uncertainties of the recommended Fluke 5700A at each source value.

Table 1-1
Recommended verification equipment

Fluke 5700A Calibrator:				
DC voltage	**AC voltage (1kHz, 50kHz)***	**DC current**	**AC current (1kHz)**	**Resistance**
100mV: ±14ppm 1.0V: ±7ppm 10V: ±5ppm 100V: ±7ppm 1000V: ±9ppm	100mV: ±200ppm 1.0V: ±82ppm 10V: ±82ppm 100V: ±90ppm 700V: ±85ppm	10mA: ±60ppm 100mA: ±70ppm 1A: ±110ppm 2.2A: ±94ppm	1A: ±690ppm 2.2A: ±682ppm	100Ω: ±17ppm 1kΩ: ±12ppm 10kΩ: ±11ppm 100kΩ: ±13ppm 1MΩ: ±18ppm 10MΩ: ±37ppm 100MΩ: ±120ppm
Fluke 5725A Amplifier: AC Voltage, 50kHz: 700V, ±375ppm				

*1kHz specifications shown. 5725A amplifier required to source 700V @ 50kHz.
90-day, 23°C ±5°C specifications shown.

NOTE: The Fluke 5725A amplifier is necessary only if you wish to verify the 750V AC range at 50kHz. Verification at 220V, 50kHz using only the 5700A calibrator is adequate for most applications.

Verification limits

The verification limits stated in this section have been calculated using only the Model 2000 one-year accuracy specifications, and they do not include test equipment uncertainty. If a particular measurement falls slightly outside the allowable range, recalculate new limits based on both Model 2000 specifications and pertinent calibration equipment specifications.

Example reading limit calculation

The following is an example of how reading limits have been calculated:

Assume you are testing the 10V DC range using a 10V input value. Using the Model 2000 one-year accuracy specification for 10V DC of ± (30ppm of reading + 5ppm of range), the calculated limits are:

Reading limits = 10V ± [(10V × 30ppm) + (10V × 5ppm)]
Reading limits = 10V ± (.0003 + .00005)
Reading limits = 10V ± .00035V
Reading limits = 9.99965V to 10.00035V

Restoring factory defaults

Before performing the verification procedures, restore the instrument to its factory defaults as follows:

1. Press SHIFT and then SETUP. The instrument will display the following prompt:

   RESTORE: FACT

NOTE *Pressing either range key toggles the RESTORE selection between USER and FACT.*

2. Restore the factory default conditions by pressing ENTER.
3. Factory defaults will be set as follows:

   Speed: medium
   Filter: 10 readings

Performing the verification test procedures

Test summary

Verification test procedures include:

- DC volts
- AC volts
- DC current
- AC current
- Resistance

If the Model 2000 is not within specifications and not under warranty, see the calibration procedures in Section 2.

Test considerations

When performing the verification procedures:

- Be sure to restore factory defaults as outlined above.
- Make sure that the equipment is properly warmed up and connected to the front panel input jacks. Also make sure that the front panel input jacks are selected with the INPUTS switch.
- Do not use autoranging for any verification tests because autorange hysteresis may cause the Model 2000 to be on an incorrect range. For each test signal, you must manually set the correct range for the Model 2000 using the range keys.
- Make sure the calibrator is in operate before you verify each measurement.
- Always let the source signal settle before taking a reading.
- Do not connect test equipment to the Model 2000 through a scanner or other switching equipment.

WARNING ***The maximum common-mode voltage (voltage between INPUT LO and chassis ground is 500 V peak. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose you to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered to avoid personal injury caused by electric shock.***

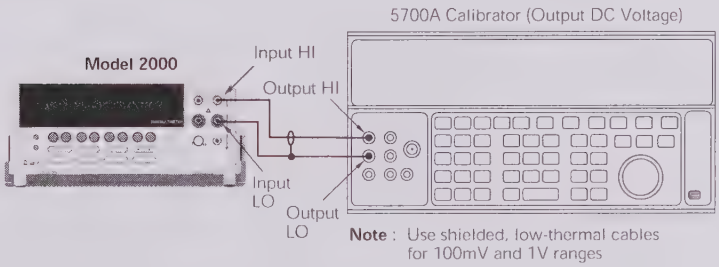
Verifying DC voltage

Check DC voltage accuracy by applying accurate DC voltages from the calibrator to the Model 2000 INPUT jacks and verifying that the display reads within specified limits. Follow these steps to verify the DC voltage:

1. Connect the Model 2000 HI and LO INPUT jacks to the DC voltage calibrator as shown in Figure 1-1.

NOTE *Use shielded, low-thermal connections when testing the 100mV and 1V ranges to avoid errors caused by noise or thermal effects. Connect the shield to the calibrator's output LO terminal.*

Figure 1-1
Connections for DC volts verification



2. Select the DC volts function by pressing the DCV key, and set the Model 2000 to the 100mV range.
3. Set the calibrator output to 0.00000mV DC, and allow the reading to settle.
4. Enable the Model 2000 REL mode. Leave REL enabled for the remainder of the DC volts verification tests.
5. Source positive and negative full-scale voltages for each of the ranges listed in Table 1-2. For each voltage setting, be sure that the reading is within stated limits.

Table 1-2
DCV reading limits

DCV Range	Applied DC voltage*	Reading limit (1 year, 18°C-28°C)
100mV	100.0000mV	99.9915 to 100.0085mV
1V	1.000000V	0.999963 to 1.000037V
10V	10.00000V	9.99965 to 10.00035V
100V	100.0000V	99.9949 to 100.0051V
1000V	1000.000V	999.939 to 1000.061V

* Source positive and negative values for each range.

Verifying AC voltage

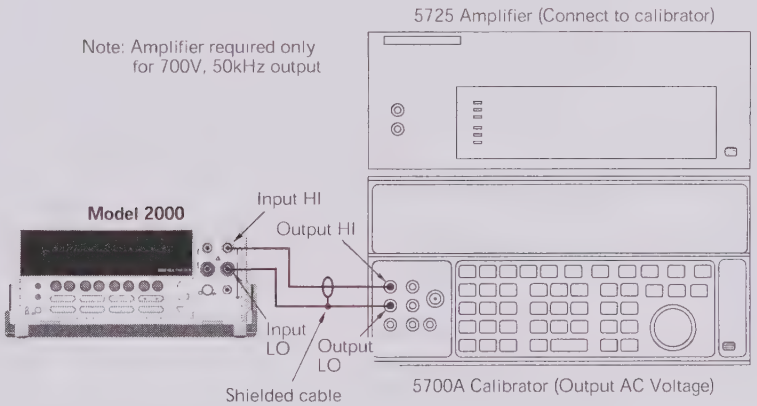
Check AC voltage accuracy by applying accurate AC voltages at specific frequencies from the calibrator to the Model 2000 inputs and verifying that the display reads within specified limits.

CAUTION ***Do not exceed 1000 V peak between INPUT HI and INPUT LO, or 8×10^7 V•Hz input, because instrument damage may occur.***

Follow these steps to verify AC voltage accuracy:

1. Connect the Model 2000 HI and LO INPUT jacks to the AC voltage calibrator as shown in Figure 1-2.

Figure 1-2
Connections for AC volts verification



2. Select the AC volts function by pressing the ACV key.
3. Set the Model 2000 for the 100mV range; make sure that REL is disabled.
4. Source 1kHz and 50kHz AC voltages for each of the ranges summarized in Table 1-3, and make sure that the respective Model 2000 readings fall within stated limits.

Table 1-3
ACV reading limits

ACV Range	Applied AC voltage	Reading limits (1 year, 18° C-28° C)	
		1kHz	50kHz
100mV	100.0000mV	99.9100 to 100.0900mV	99.8300 to 100.1700mV
1V	1.000000V	0.999100 to 1.000900V	0.998300 to 1.001700V
10V	10.00000V	9.99100 to 10.00900V	9.98300 to 10.01700V
100V	100.0000V	99.9100 to 100.0900V	99.8300 to 100.1700V
750V	700.000V*	699.355 to 700.645V	698.785 to 701.215V

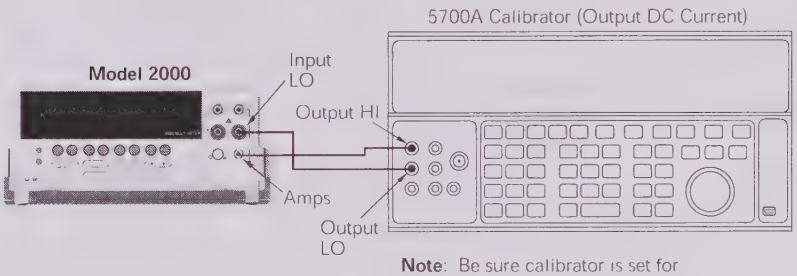
*If the 5725A amplifier is not available, change the 700V @ 50kHz step to 219V @ 50kHz. (Reading limits for 219V @ 50kHz 218.362 to 219.638V.)

Verifying DC current

Check DC current accuracy by applying accurate DC currents from the calibrator to the AMPS input of the Model 2000 and verifying that the display reads within specified limits. Follow these steps to verify DC current accuracy:

1. Connect the Model 2000 AMPS and INPUT LO jacks to the calibrator as shown in Figure 1-3.
2. Select the DC current measurement function by pressing the DCI key.
3. Set the Model 2000 for the 10mA range.
4. Source positive and negative full-scale currents for each of the ranges listed in Table 1-4, and verify that the readings for each range are within stated limits.

Figure 1-3
Connections for DC current verification



Note: Be sure calibrator is set for normal current output.

Table 1-4
DCI limits

DCI Range	Applied DC current*	Reading limits (1 year, 18°C-28°C)
10mA	10.0000mA	9.99460 to 10.00540mA
100mA	100.0000mA	99.9100 to 100.0900mA
1A	1.000000A	0.999160 to 1.000840A
3A	2.20000A	2.19732 to 2.20268A

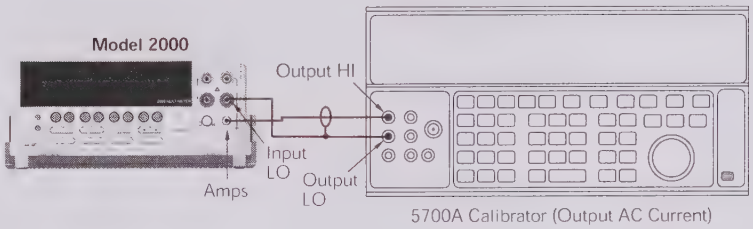
* Source positive and negative currents with values shown.

Verifying AC current

Check AC current accuracy by applying accurate AC current at specific frequencies from the calibrator to the Model 2000 input and verifying that the display reads within specified limits. Follow these steps to verify the AC current:

1. Connect the Model 2000 AMPS and INPUT LO jacks to the calibrator as shown in Figure 1-4.

Figure 1-4
Connections for AC current verification



2. Select the AC current function by pressing the ACI key.
3. Set the Model 2000 for the 1A range.
4. Source 1A and 2.2A, 1kHz AC currents as summarized in Table 1-5, and verify that the readings are within stated limits.

Table 1-5
ACI limits

ACI Range	Applied AC current	Reading limits (1 year, 18°C-28°C) 1kHz
1A	1.000000A	0.998600 to 1.001400A
3A	2.20000A	2.19490 to 2.20510A

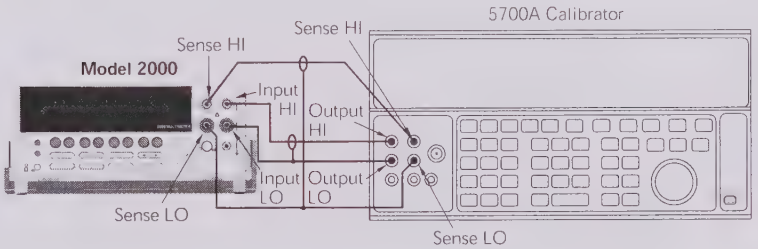
Verifying resistance

Check resistance by connecting accurate resistance values from the calibrator to the Model 2000 and verifying that its resistance readings are within the specified limits.

Follow these steps to verify resistance accuracy:

1. Using shielded 4-wire connections, connect the Model 2000 INPUT and SENSE jacks to the calibrator as shown in Figure 1-5.
2. Set the calibrator for 4-wire resistance with external sense on.
3. Select the Model 2000 4-wire resistance function by pressing the Ω4 key.
4. Set the Model 2000 for the 100Ω range, and make sure the FILTER is on.
5. Recalculate the limits in Table 1-6 based on actual calibrator resistance values.
6. Source the nominal full-scale resistance values for 100Ω-10MΩ ranges summarized in Table 1-6, and verify that the readings are within stated limits.

Figure 1-5
Connections for resistance verification (100Ω-10MΩ ranges)

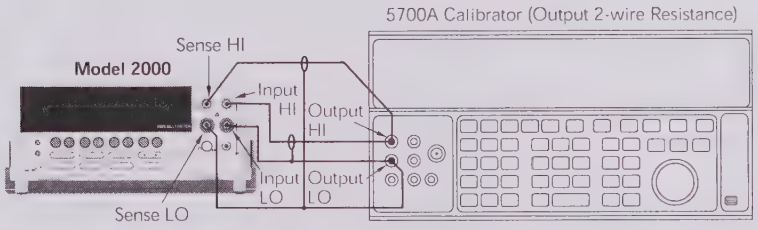


Note : Use shielded low-thermal cables to minimize noise. Enable or disable calibrator external sense as indicated in procedure.

7. Connect the Model 2000 INPUT and SENSE jacks to the calibrator as shown in Figure 1-6.
8. Disable external sense on the calibrator.
9. Set the Model 2000 to the 100MΩ range.
10. Source a nominal 100MΩ resistance value, and verify the reading is within the limits for the 100MΩ range listed in Table 1-6.

Table 1-6
Limits for resistance verification

Ω Range	Nominal applied resistance	Nominal reading limits (1 year, 18°C-28°C)	Recalculated limits	
			Low limit	High limit
100Ω	100Ω	99.9860 to 100.0140Ω		
1kΩ	1kΩ	0.999890 to 1.000110kΩ		
10kΩ	10kΩ	9.99890 to 10.00110kΩ		
100kΩ	100kΩ	99.9890 to 100.0110kΩ		
1MΩ	1MΩ	0.999890 to 1.000110MΩ		
10MΩ	10MΩ	9.99590 to 10.00410MΩ		
100MΩ	100MΩ	99.8470 to 100.1530MΩ		



Note Use shielded cables to minimize noise
Disable calibrator external sense mode

Figure 1-6
Connections for resistance verification (100MΩ range)

2
Calibration

Introduction

Use the procedures in this section to calibrate the Model 2000. Calibration procedures include:

- **Comprehensive calibration:** Calibrate DC and AC voltages, DC and AC currents, and resistance values.
- **Manufacturing calibration:** Usually only performed at the factory.

WARNING ***This information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.***

All the procedures require accurate calibration equipment to supply precise DC and AC voltages, DC and AC currents, and resistance values. Comprehensive AC and DC calibration can be performed any time by a technician either from the front panel, or by using the SCPI commands sent either over the IEEE-488 bus or the RS-232 link.

NOTE *Manufacturing calibration is required in the field only if the Model 2000 has been repaired.*

This section includes the following information:

Environmental conditions: Explains the type of environment needed for calibration.

Calibration considerations: Summarizes test conditions to observe when performing calibration.

Calibration code: Explains how to enter the calibration code to unlock Model 2000 calibration.

Comprehensive calibration: Summarizes the calibration cycle and also lists recommended comprehensive calibration equipment.

Front panel calibration: Provides the calibration procedures using the front panel.

SCPI command calibration: Provides the detailed procedures for calibrating the Model 2000 using SCPI commands.

Manufacturing calibration: Explains the manufacturing calibration procedure using both the front panel and SCPI commands.

Environmental conditions

Conduct the calibration procedures in a location that has:

- An ambient temperature of 23°C ±5°C
- A relative humidity of less than 80% unless otherwise noted

Warm-up period

Allow the Model 2000 Multimeter to warm up for at least one hour before performing calibration.

If the instrument has been subjected to temperature extremes (those outside the ranges stated in the above section) allow extra time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 2000 Multimeter requires a line voltage of 100V/120V/220V/240V, ±10% and a line frequency of 45Hz to 66Hz or 360Hz to 440Hz.

Calibration considerations

When performing the calibration procedures:

- Make sure that the equipment is properly warmed up and connected to the appropriate input jacks. Also make sure that the correct input jacks are selected with the INPUTS switch.
- Make sure the calibrator is in operate before you complete each calibration step.
- Always let the source signal settle before calibrating each point.
- Do not connect test equipment to the Model 2000 through a scanner or other switching equipment.
- If an error occurs during calibration, the Model 2000 will generate an appropriate error message. See Section 3 and Appendix B for more information.

WARNING ***The maximum common-mode voltage (voltage between INPUT LO and chassis ground) is 500 V peak. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose you to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered to avoid personal injury caused by electric shock.***

Calibration code

Comprehensive calibration code

Before performing comprehensive (user) calibration, you must first unlock calibration by entering the appropriate calibration code.

Front panel calibration code

For front panel calibration, follow these steps:

1. Access the calibration menu by pressing SHIFT then CAL, and note that the instrument displays the following:

   CAL: DATES

2. Use the up or down range keys to scroll through the available calibration parameters until the unit displays RUN, then press ENTER.
3. The Model 2000 then prompts you to enter a code. (The factory default code is 002000.) Use the left and right arrow keys to move among the digits; use the up range key to increment numbers, and press the down range key to specify alphabetic letters. Confirm the code by pressing ENTER.
4. The Model 2000 allows you to define a new calibration code. Use the up and down range keys to toggle between yes and no. Choose N if you do not want to change the code. Choose Y if you want to change the code. The unit then prompts you to enter a new code. Enter the code, and press ENTER.

Programming the calibration code

If you are performing calibration over the IEEE-488 bus or the RS-232 link, send this command to unlock the calibration lock:

:CAL:PROT:CODE <up to 8-character string>

The default code command is:

:CAL:PROT:CODE 'KI002000'

Manufacturing calibration lock

To unlock manufacturing calibration, press and hold the front panel OPEN key while turning on the power. See Manufacturing calibration at the end of this section for procedures.

Comprehensive calibration

The comprehensive calibration procedure calibrates the DCV, DCI, ACV, ACI, and ohms functions You can also choose to calibrate only DCV/DCI and resistance, or the ACV/ACI functions.

These procedures are usually the only ones required in the field. Manufacturing calibration is done at the factory and should be done if the unit has been repaired in the field. See the Manufacturing calibration paragraph at the end of this section for more information.

Calibration cycle

Perform comprehensive calibration at least once a year, or every 90 days to ensure the unit meets the corresponding specifications.

Recommended equipment

Table 2-1 lists the recommended equipment you need for comprehensive, DC only, and AC only calibration procedures. You can use alternate equipment, such as a DC transfer standard and characterized resistors, as long that equipment has specifications at least as good as those listed in the table.

Table 2-1
Recommended equipment for comprehensive, DC only, or AC only calibration

Fluke 5700A Calibrator				
DC voltage	**AC voltage (1kHz, 50kHz)***	**DC current**	**AC current (1kHz)**	**Resistance**
10V: ±5ppm 100V: ±7ppm	10mV: ±710ppm 100mV: ±200ppm 1.0V: ±82ppm 10V: ±82ppm 100V: ±90ppm 700V: ±85ppm	10mA: ±60ppm 100mA: ±70ppm 1A: ±110ppm	100mA: ±190ppm 1A: ±690ppm 2A: ±670ppm	1kΩ: ±12ppm 10kΩ: ±11ppm 100kΩ: ±13ppm 1MΩ: ±18ppm
Keithley 8610 Low-thermal shorting plug				

*1kHz specifications. 10mV and 700V points require 1kHz only.
All calibration specifications are 90-day, 23° ±5°C specifications.

Canceling calibration

You can cancel the calibration process at any time by pressing EXIT.

Front panel calibration

Follow the steps in the following paragraphs for comprehensive, DC only, and AC only calibration procedures.

The procedures for front panel calibration include:

- Preparing the Model 2000 for calibration
- Front panel short and open calibration
- DC voltage calibration
- Resistance calibration
- DC current calibration
- AC voltage calibration
- AC current calibration
- Setting calibration dates

Preparing the Model 2000 for calibration

1. Turn on the Model 2000, and allow it to warm up for at least one hour before performing the calibration procedure.
2. Select the DCV function and choose SLOW as the RATE (integration time = 10 PLC).
3. Start the calibration process as follows:
   A. Access the calibration menu by pressing SHIFT then CAL.
   B. Use the up and down range keys to scroll through the available calibration menu items until the unit displays RUN, then press ENTER.
   C. At the prompt, enter the calibration code. (The default code is 002000.) Use the left and right arrow keys to move among the digits; use the up range key to increment numbers, and press the down range key to specify alphabetic letters. Confirm the code by pressing ENTER.
   D. Choose N at the prompt to proceed without changing the code, then press ENTER.
4. Choose which of the the calibration tests summarized in Table 2-2 you want to run at the CAL: RUN prompt. Use the up and down range keys to scroll through the options; select your choice by pressing ENTER.

Table 2-2
Comprehensive calibration procedures

Procedure	Menu choice	Procedures
Full calibration	ALL	All comprehensive calibration steps.
DCV, DCI, and ohms	DC	DC voltage, DC current, and resistance calibration.
ACV and ACI	AC	AC voltage and AC current calibration.

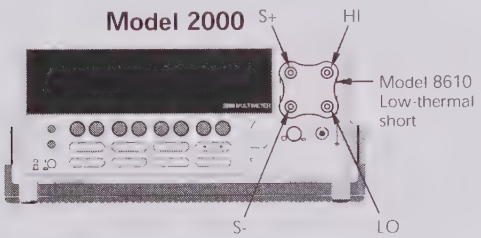
Front panel short and open calibration

At the Model 2000 prompt for a front panel short, do the following:

1. Connect the Model 8610 low-thermal short to the instrument front panel INPUT and SENSE terminals as shown in Figure 2-1. Make sure the INPUTS button is not pressed in so that the front inputs are selected. Wait at least three minutes before proceeding to allow for thermal equilibrium.

NOTE *Be sure to connect the low-thermal short properly to the HI, LO, and SENSE terminals. Keep drafts away from low-thermal connections to avoid thermal drift, which could affect calibration accuracy.*

Figure 2-1
Low-thermal short connections



2. Press ENTER to start short-circuit calibration. While the unit is calibrating, the unit will display:

   CALIBRATING

3. When the unit is done calibrating, it will display the following prompt:

   OPEN CIRCUIT

4. Remove the calibration short, and press ENTER. During this phase, the CALIBRATING message will be displayed.

DC voltage calibration

After the front panel short and open procedure, the unit will prompt you for the first DC voltage: +10V. Do the following:

1. Connect the calibrator to the Model 2000 as shown in Figure 2-2. Wait three minutes to allow for thermal equilibrium before proceeding.

NOTE *Although 4-wire connections are shown, the sense leads are connected and disconnected at various points in this procedure by turning calibrator external sense on or off as appropriate. If your calibrator does not have provisions for turning external sense on and off, disconnect the sense leads when external sensing is to be turned off, and connect the sense leads when external sensing is to be turned on.*

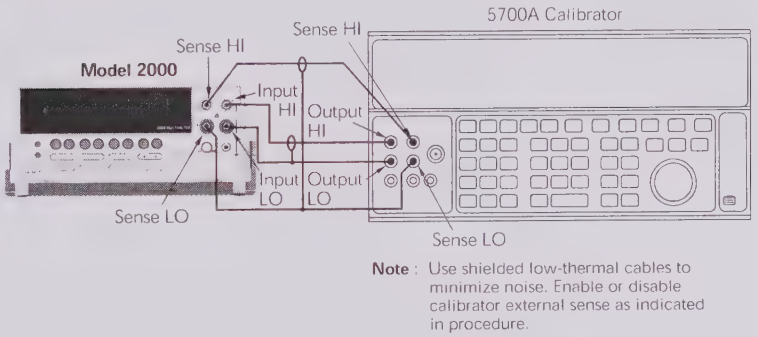


Figure 2-2
Calibrator connections for DC volts and ohms portion of comprehensive calibration

2. Set the calibrator to output DC volts, and turn external sense off.
3. Perform the steps listed in Table 2-3 to complete DC volts calibration. For each calibration step:
   - Set the calibrator to the indicated value, and make sure it is in operate.
   - Press the ENTER key to calibrate that step.
   - Wait until the Model 2000 finishes each step. (The unit will display the CALIBRATING message while calibrating.)

NOTE *If your calibrator cannot output the values recommended in Table 2-3, use the left and right arrow keys, and the up and down range keys to set the Model 2000 display value to match the calibrator output voltage.*

Table 2-3
DC volts calibration summary

Calibration step	Calibrator voltage	Allowable range
+10V	+10.00000V	+9V to +11V
-10V	-10.00000V	-9V to -11V
100V	+100.0000V	+90V to +110V

Resistance calibration

Completing the 100V DC calibration step ends the DC voltage calibration procedure. The Model 2000 will then prompt you to connect 1 kΩ. Follow these steps for resistance calibration:

1. Set the calibrator output for resistance, and turn on external sense.

NOTE *Use external sense (4-wire Ω) when calibrating all resistance ranges. Be sure that the calibrator external sense mode is turned on.*

2. Perform the calibration steps summarized in Table 2-4. For each step:
   - Set the calibrator to the indicated value, and place the unit in operate. (If the calibrator cannot output the exact resistance value, use the Model 2000 left and right arrow keys and the range keys to adjust the Model 2000 display to agree with the calibrator resistance.)
   - Press the ENTER key to calibrate each point.
   - Wait for the Model 2000 to complete each step before continuing.

Table 2-4
Ohms calibration summary

Calibration step	Calibrator resistance*	Allowable range
1kΩ	1kΩ	0.9kΩ to 1.1kΩ
10kΩ	10kΩ	9kΩ to 11kΩ
100kΩ	100kΩ	90kΩ to 110kΩ
1MΩ	1MΩ	0.9MΩ to 1.1MΩ

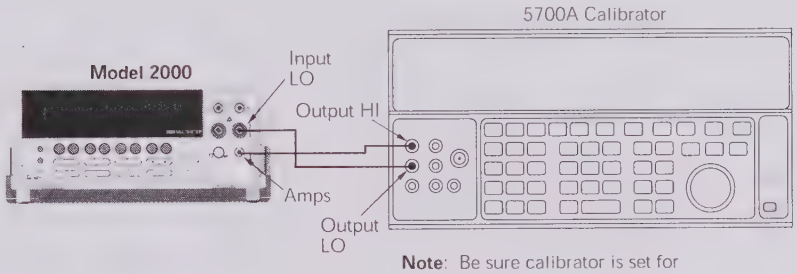
* Nominal resistance. Adjust Model 2000 calibration parameter to agree with actual value.

DC current calibration

After the 1MΩ resistance point has been calibrated, the unit will prompt you for 10mA. Follow these steps for DC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2000 as shown in Figure 2-3.

Figure 2-3
Connections for DC and AC amps comprehensive calibration



Note: Be sure calibrator is set for normal current output.

2. Calibrate each current step summarized in Table 2-5. For each step:
   - Set the calibrator to the indicated DC current, and make sure the unit is in operate.
   - Make sure the Model 2000 display indicates the correct calibration current.
   - Press ENTER to complete each step.
   - Allow the Model 2000 to finish each step.

NOTE *If you are performing DC-only calibrator, proceed to the "Setting calibration dates" paragraph.*

Table 2-5
DC current calibration summary

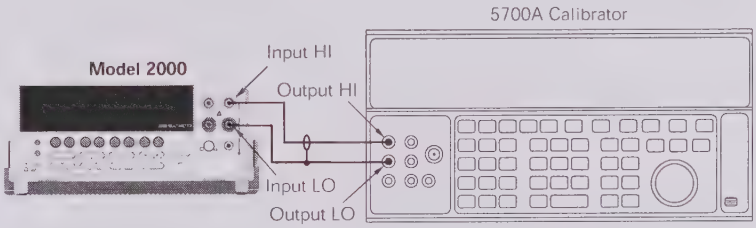
Calibration step	Calibrator current	Allowable range
10mA	10.00000mA	9mA to 11mA
100mA	100.0000mA	90mA to 110mA
1A	1.00000A	0.9A to 1.1A

AC voltage calibration

Follow these steps for AC voltage calibration:

1. Connect the calibrator to the Model 2000 INPUT HI and LO terminals as shown in Figure 2-4.

Figure 2-4
Connections for AC volts calibration



2. Perform the calibration steps summarized in Table 2-6. For each step:
   - Set the calibrator to the indicated value, and make sure the calibrator is in operate.
   - Press ENTER to complete each step.
   - Wait until the Model 2000 completes each step.

Table 2-6
AC voltage calibration summary

Calibration step	Calibrator voltage, frequency
10mV AC at 1kHz	10.00000mV, 1kHz
100mV AC at 1kHz	100.0000mV, 1kHz
100mV AC at 50kHz	100.0000mV, 50kHz
1V AC at 1kHz	1.000000V, 1kHz
1V AC at 50kHz	1.000000V, 50kHz
10V AC at 1kHz	10.00000V, 1kHz
10V AC at 50kHz	10.00000V, 50kHz
100V AC at 1kHz	100.0000V, 1kHz
100V AC at 50kHz	100.0000V, 50kHz
700V AC at 1kHz	700.000V, 1kHz

AC current calibration

After the 700VAC at 1kHz point has been calibrated, the unit will prompt you for 100mA at 1kHz. Follow these steps for AC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2000 as shown in Figure 2-3.
2. Perform the calibration steps summarized in Table 2-7. For each step:
   - Set the calibrator to the indicated current and frequency, and make sure the unit is in operate.
   - Press ENTER to complete each calibration step.
   - Allow the unit to complete each step before continuing.

Table 2-7
AC current calibration summary

Calibration step	Calibrator voltage, frequency
100mA at 1kHz	100.0000mA, 1kHz
1A at 1kHz	1.000000A, 1kHz
2A at 1kHz	2.000000A, 1kHz

Setting calibration dates

At the end of the calibration procedure, the instrument will display the CALIBRATION COMPLETE message. Press ENTER to continue, and the the Model 2000 will prompt you to enter the calibration date and the calibration due date. Set these dates as follows:

1. At the CAL DATE: mm/dd/yy prompt, use the left and right arrow keys, and the range keys to set the calibration date, then press ENTER.
2. The unit will then prompt you to enter the next calibration due date with this prompt: CAL NDUE: mm/dd/yy. Use the left and right arrow keys, and the range keys to set the calibration due date, then press ENTER.
3. The unit will prompt you to save new calibration constants with this message: SAVE CAL? YES. To save the new constants, press ENTER. If you do not want to save the new constants, press the down range key to toggle to NO, then press ENTER.

NOTE *Calibration constants calculated during the current calibration procedure will not be saved unless you choose the YES option. Previous calibration constants will be retained if you select NO.*

SCPI command calibration

Follow the steps in this section to use SCPI commands to perform comprehensive, DC only, and AC only calibration procedures. See Section 3 for a detailed list and description of SCPI calibration commands.

When sending calibration commands, be sure that the Model 2000 completes each step before sending the next command. You can do so either by observing the front panel CALIBRATING message, or by Detecting the completion of each step over the bus. (See "Detecting calibration step completion" at the end of Section 3.)

The procedures for calibrating the Model 2000 using SCPI commands include:

- Preparing the Model 2000 for calibration
- Front panel short and open calibration
- DC voltage calibration
- Resistance calibration
- DC current calibration
- AC voltage calibration
- AC current calibration
- Programming calibration dates
- Saving calibration constants
- Locking out calibration

NOTE *As with front panel calibration, you can choose to perform complete, DC-only, or AC-only calibration. When sending calibration commands, be sure to include a space character between each command and parameter.*

Preparing the Model 2000 for calibration

1. Connect the Model 2000 to the IEEE-488 bus of the computer using a shielded IEEE-488 cable, such as the Keithley Model 7007, or connect the unit to a computer through an RS-232 port using a straight-through 9-pin to 9-pin cable (use a 9-25-pin adapter if necessary).
2. Turn on the Model 2000, and allow it to warm up for an hour before performing calibration.
3. Select the DCV function and choose SLOW as the RATE (integration time = 10 PLC).
4. Make sure the primary address of the Model 2000 is the same as the address specified in the program that you will be using to send commands. (Use the GPIB key.)
5. Unlock the calibration function by sending this command:

   :CAL:PROT:CODE 'KI002000'

   (The above command shows the default code, KI002000. Substitute the correct code if changed.)
6. Send the following command to initiate calibration:

   :CAL:PROT:INIT

Front panel short and open calibration

1. Connect the Model 8610 low-thermal short to the instrument INPUT and SENSE terminals as shown in Figure 2-1. Make sure the INPUTS button is not pressed in so that the front inputs are active. Wait at least three minutes before proceeding to allow for thermal equilibrium.

NOTE *Be sure to connect the low-thermal short properly to the HI, LO, and SENSE terminals. Keep drafts away from low-thermal connections to avoid thermal drift, which could affect calibration accuracy.*

2. Send the following command:

   :CAL:PROT:DC:STEP1

3. After the Model 2000 completes this step, remove the short, and send this command:

   :CAL:PROT:DC:STEP2

DC voltage calibration

After front panel short and open steps, do the following:

1. Connect the calibrator to the Model 2000 as shown in Figure 2-2. Allow three minutes for thermal equilibrium.

NOTE *Although 4-wire connections are shown, the sense leads are connected and disconnected at various points in this procedure by turning calibrator external sense on or off as appropriate. If your calibrator does not have provisions for turning external sense on and off, disconnect the sense leads when external sensing is to be turned off, and connect the sense leads when external sensing is to be turned on.*

2. Perform the calibration steps summarized in Table 2-8. For each step:
   - Set the calibrator to the indicated voltage, and make sure the unit is in operate. (Use the recommended voltage if possible.)
   - Send the indicated programming command.
   - Wait until the Model 2000 completes each step before continuing.

Table 2-8
DC voltage calibration programming steps

Calibration step	Calibrator voltage	Calibration command*	Parameter range
+10V	+10.00000V	:CAL:PROT:DC:STEP3 10	9 to 11
-10V	-10.00000V	:CAL:PROT:DC:STEP4 -10	-9 to -11
100V	100.0000V	:CAL:PROT:DC:STEP5 100	90 to 110

* Change parameter accordingly if using a different calibrator voltage.

Resistance calibration

Follow these steps for resistance calibration:

1. Set the calibrator to the resistance mode, and turn on external sensing.

NOTE *Use external sense (4-wire Ω) when calibrating all resistance ranges. Be sure that the calibrator external sense mode is turned on.*

2. Perform the calibration steps summarized in Table 2-9. For each step:
   - Set the calibrator to the indicated resistance, and make sure the unit is in operate. (Use the recommended resistance or the closest available value.)
   - Send the indicated programming command. (Change the command parameter if you are using a different calibration resistance than that shown.)
   - Wait until the Model 2000 completes each step before continuing.

Table 2-9
Resistance calibration programming steps

Calibration step	Calibrator resistance	Calibration command*	Parameter range
1kΩ	1kΩ	:CAL:PROT:DC:STEP6 1E3	900 to 1.1E3
10kΩ	10kΩ	:CAL:PROT:DC:STEP7 10E3	9E3 to 11E3
100kΩ	100kΩ	:CAL:PROT:DC:STEP8 100E3	90E3 to 110E3
1MΩ	1MΩ	:CAL:PROT:DC:STEP9 1E6	900E3 to 1.1E6

* Use exact calibrator resistance value for parameter.

DC current calibration

After the 1MΩ resistance point has been calibrated, follow these steps for DC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2000 as shown in Figure 2-3.
2. Perform the calibration steps listed in Table 2-10. For each step:
   - Set the calibrator to the indicated current, and make sure the unit is in operate. (Use the recommended current if possible.)
   - Send the indicated programming command. (Change the current parameter if you are using a different calibration current.)
   - Wait until the Model 2000 completes each step before continuing.

NOTE *If you are performing DC-only calibration, proceed to the "Programming calibration dates" paragraph.*

Table 2-10
DC current calibration programming steps

Calibration step	Calibrator current	Calibration command*	Parameter range
10mA	10.00000mA	:CAL:PROT:DC:STEP10 10E-3	9E-3 to 11E-3
100mA	100.00000mA	:CAL:PROT:DC:STEP11 100E-3	90E-3 to 110E-3
1A	1.000000A	:CAL:PROT:DC:STEP12 1	0.9 to 1.1

* Change parameter if using a different current.

AC voltage calibration

Follow these steps for AC voltage calibration:

1. Connect the calibrator to the Model 2000 INPUT HI and LO terminals as shown in Figure 2-4.
2. Perform the calibration steps summarized in Table 2-11. For each step:
   - Set the calibrator to the indicated voltage and frequency, and make sure the unit is in operate. (You must use the stated voltage and frequency.)
   - Send the indicated programming command.
   - Wait until the Model 2000 completes each step before continuing.

Table 2-11
AC voltage calibration programming steps

Calibration step	Calibrator voltage, frequency	Calibration command
10mV AC at 1kHz	10.00000mV, 1kHz	:CAL:PROT:AC:STEP1
100mV AC at 1kHz	100.0000mV, 1kHz	:CAL:PROT:AC:STEP2
100mV AC at 50kHz	100.0000mV, 50kHz	:CAL:PROT:AC:STEP3
1VAC at 1kHz	1.000000V, 1kHz	:CAL:PROT:AC:STEP4
1VAC at 50kHz	1.000000V, 50kHz	:CAL:PROT:AC:STEP5
10VAC at 1kHz	10.00000V, 1kHz	:CAL:PROT:AC:STEP6
10VAC at 50kHz	10.00000V, 50kHz	:CAL:PROT:AC:STEP7
100VAC at 1kHz	100.0000V, 1kHz	:CAL:PROT:AC:STEP8
100VAC at 50kHz	100.0000V, 50kHz	:CAL:PROT:AC:STEP9
700VAC at 1kHz	700.000V, 1kHz	:CAL:PROT:AC:STEP10

AC current calibration

Follow these steps for AC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2000 as shown in Figure 2-3.
2. Perform the calibration steps summarized in Table 2-12. For each step:
   - Set the calibrator to the indicated current and frequency, and make sure the unit is in operate. (You must use the stated current and frequency.)
   - Send the indicated programming command.
   - Wait until the Model 2000 completes each step before continuing.

Table 2-12
AC current calibration programming steps

Calibration step	Calibrator current, frequency	Calibration command
100mA at 1kHz	100.0000mA, 1kHz	:CAL:PROT:AC:STEP11
1A at 1kHz	1.000000A, 1kHz	:CAL:PROT:AC:STEP12
2A at 1kHz	2.000000A, 1kHz	:CAL:PROT:AC:STEP13

Programming calibration dates

Program the present calibration date and calibration due date by sending the following commands:

```
:CAL:PROT:DATE <year>, <month>, <day>
:CAL:PROT:NDUE <year>, <month>, <day>
```

For example, the following commands assume calibration dates of 12/15/95 and 3/14/96 respectively:

```
:CAL:PROT:DATE 1995, 12, 15
:CAL:PROT:NDUE 1996, 3, 14
```

Saving calibration constants

After completing the entire calibration procedure, send the following command to save the new calibration constants:

```
:CAL:PROT:SAVE
```

NOTE *Calibration constants will not be saved unless the :SAVE command is sent.*

Locking out calibration

After saving calibration, send the following command to lock out calibration:

```
:CAL:PROT:LOCK
```

Manufacturing calibration

The manufacturing procedure is normally performed only at the factory, but the necessary steps are included here in case the unit is repaired, and the unit requires these calibration procedures.

NOTE *If the unit has been repaired, the entire comprehensive calibration procedure should also be performed in addition to the manufacturing calibration procedure.*

Recommended test equipment

Table 2-13 summarizes the test equipment required for the manufacuring calibration steps. In addition, you will need the Fluke 5700A Calibrator (see Table 2-1) to complete the comprehensive calibration steps.

Table 2-13
Recommended equipment for manufacturing calibration

Keithley 3930A or 3940 Frequency Synthesizer: 1V RMS, 3Hz: ±5ppm 1V RMS, 1kHz: ±5ppm
Keithley Model 2001 or 2002 DMM: 1V, 3Hz AC, ±0.13%
Keithley Model 8610 Low-thermal shorting plug

Unlocking manufacturing calibration

To unlock manufacturing calibration, press and hold in the OPEN key while turning on the power.

Measuring the synthesizer voltage

The 3Hz synthesizer signal amplitude must be accurately measured using the digital multimeter listed in Table 2-13. Proceed as follows:

1. Connect the synthesizer output to the digital multimeter input jacks (see Figure 2-5).
2. Turn on the synthesizer and multimeter, and allow a one-hour warm-up period before measuring.
3. Set the synthesizer to output a 1V RMS sine wave at 3Hz; measure and record the signal amplitude.

Front panel calibration

1. Connect the low-thermal short to the rear panel input jacks, and select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.
2. Press in and hold the OPEN key while turning on the power.
3. Press SHIFT then CAL, select RUN, then enter the appropriate calibration code (default: 002000).
4. Select ALL at the CAL:RUN prompt.
5. Press ENTER.
6. Perform the entire front panel comprehensive calibration procedure discussed earlier in this section.
7. Connect the synthesizer to the Model 2000 INPUT jacks as shown in Figure 2-5. Select the front input jacks with the INPUTS switch.
8. After the last AC current calibration step, the instrument will prompt you to enter 3Hz at 1V RMS and 1kHz. For each prompt:
   - Low frequency cal: Set the synthesizer to output a 1V RMS, 3Hz sine wave. Use the left and right arrow keys, and the range keys to adjust the displayed voltage value to the value you measured and recorded earlier. Press Enter.
   - Frequency cal: Set the synthesizer to output a 1V RMS sine wave at 1kHz. Enter 1.000000kHz, then press ENTER.
9. Set the calibration dates, then save calibration constants to complete the process.

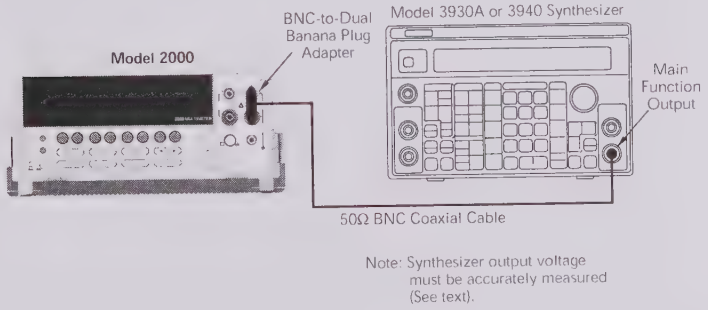

Model 2000
BNC-to-Dual Banana Plug Adapter
Model 3930A or 3940 Synthesizer
Main Function Output
50Ω BNC Coaxial Cable
Note: Synthesizer output voltage must be accurately measured (See text).

Figure 2-5
Synthesizer connections for manufacturing calibration

SCPI command calibration

1. Connect the low-thermal short to the rear panel input jacks, and select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.
2. Press in and hold the OPEN key while turning on the power.
3. Enable calibration by sending the :CODE command. For example, the default command is:

   :CAL:PROT:CODE 'KI002000'

4. Initiate calibration by sending the following command:

   :CAL:PROT:INIT

5. Calibrate step 0 with the following command:

   :CAL:PROT:AC:STEP0

6. Perform the entire SCPI command comprehensive calibration procedure discussed earlier in this section.
7. Connect the synthesizer to the Model 2000 INPUT jacks as shown in Figure 2-5. Select the front input jacks with the INPUTS switch.
8. Set the synthesizer output to 1V RMS at 3Hz, then send the following command:

   :CAL:PROT:AC:STEP14 <Cal_voltage>

   Here <Cal_voltage> is the actual 3Hz synthesizer signal amplitude you recorded earlier.

9. Set the synthesizer output to 1V RMS at 1kHz, then send the following command:

   :CAL:PROT:AC:STEP15 1E3

10. Send the following commands to set calibration dates, save calibration constants, and lock out calibration:

    :CAL:PROT:DATE <year>, <month>, <day>
    :CAL:PROT:NDUE <year>, <month>,<day>
    :CAL:PROT:SAVE
    :CAL:PROT:LOCK

NOTE *After manufacturing calibration is unlocked, you have the option of performing comprehensive, DC-only, or AC-only calibration. If you calibrate DC-only and then lock out calibration, manufacturing calibration is then locked, and you cannot then perform AC calibration. You must then unlock manufacturing calibration by holding in the OPEN key and cycling power.*

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